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**WATER QUALITY RESEARCH--THE PRESIDENT'S INITIATIVE
PROGRAM REVIEW AND EVALUATION
1992**

PRIORITY COMPONENTS

COMPREHENSIVE REPORT

SOUTH REGION

**Agricultural Research Service
Cooperative State Research Service
U.S. Department of Agriculture**

**in Cooperation
with**

**State Agricultural Experiment Stations
and other Collaborators**

**at
Baton Rouge, Louisiana**

**United States
Department of
Agriculture**



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ACKNOWLEDGEMENT

Many people contributed to the success of the 1992 evaluation and review of the water quality research program supported largely by FY 1990 and 1991 funds from the President's Initiative on Water Quality, awarded through the Agricultural Research Service (ARS) and Cooperative State Research Service (CSRS) of the U.S. Department of Agriculture.

Baton Rouge, Louisiana and Tucson, Arizona were selected as sites for the southern and western regions, respectively. Planning was largely through efforts of administrators and scientists of the State agricultural experiment stations (SAES), ARS and CSRS. We appreciated guidance from SAES administrative advisors for water quality V. V. Volk, Oregon and J. M. Davidson, Florida. Significant assistance was provided by C. B. Rumburg, J. M. Horton, and B. L. Schmidt of CSRS, D. A. Bucks, ARS, H. Mattraw, U.S. Geological Survey, and others. In addition to the above, effectiveness of the meetings was enhanced through participation by representatives of the Extension Service, Soil Conservation Service, Economic Research Service and the fertilizer and chemical industries.

Members of the Evaluation Panels for the two meetings are the following. They are also listed as Work Shop Participants at the end of each Research Problem Area (RPA) work group report.

D. E. Albrecht
Texas A&M University

L. L. Boersma
Oregon State University

B. G. Ellis
Michigan State University

W. C. Koskinen
ARS-USDA, St. Paul, MN

R. Lal
Ohio State University

K. L. Wells
University of Kentucky

H.H. Cheng
University of Minnesota

C. T. Haan
Oklahoma State University

J. F. Power
ARS-USDA, Lincoln, NE

R. S. Rauschkolb
University of Arizona

H. D. Scott
University of Arkansas

R. J. Suppalla
University of Nebraska

Appreciation is extended to these panelists for many hours of study and evaluation of the large number of abstracts and progress reports prepared by the researchers. Their analysis reports at the beginning of the meetings were a stimulus for discussions that followed in the respective RPA Work Groups. Their final reports, contained herein, show many important accomplishments of this young research program. And, the recommendations from the work groups provided guidance for emphasis in the forthcoming request for proposals of research for the fiscal year 1993 competition.

A special thanks is extended to the hosts and local organizers, whose efforts were largely responsible for efficiency of program operations and a very warm welcome. Some of those for Baton Rouge were H. R. Caffey, Chancellor, Louisiana State University (LSU) Agricultural Center and K. W. Tipton, Vice Chancellor/Director, and arrangements organizers H. M. Selim, LSU, and J. L. Fouss and G. H. Willis, ARS. University of Arizona (UA) hosts were E. G. Sander, Dean and P. J. Wierenga, Soil and Water Science-Head, arrangements organizer was A. W. Warrick, UA, with assistance by L. J. Lane, ARS and others.

The evaluation and review process and the Comprehensive Reports and Summary were coordinated and edited by C. M. Smith, Visiting Professor, Pennsylvania State University.

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FOREWORD

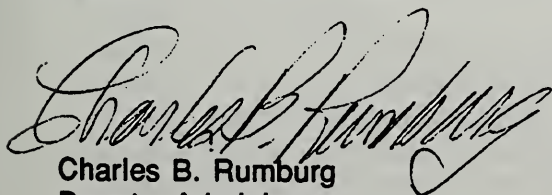
The use of pesticides, fertilizers, manures and wastes contributes substantially to the productivity and efficiency of agriculture and to the well-being of rural and urban communities. There are concerns, however, about contaminant risk to human health, water quality, and an ecologically stable environment. The President's Initiative on Water Quality was initiated in 1990 to provide new and expanded emphasis on the protection and enhancement of our water resources.

This action provided major impetus to the USDA Water Quality Research Plan developed jointly and implemented in 1989 by the Agricultural Research Service (ARS), the Cooperative State Research Service (CSRS), the State agricultural experiment stations and other agencies. The need for a far-reaching research effort on water quality problems related to agriculture was recognized, fostering an effective partnership accomplished through collaborative administrative and research efforts among USDA, U.S. Geological Survey, the Environmental Protection Agency, and State experiment stations.

This report is the result of formal water quality research program evaluations and reviews in 1992 at Baton Rouge, Louisiana and Tucson, Arizona for the South and West regions, respectively. It portrays high priority problems needing research along with recommendations of changes in program emphasis. The recommendations reflect concerns from a broad spectrum of participants including researchers in areas of expertise relevant to water quality, technologists and specialists from the Soil Conservation Service and the Extension Service (Federal and State), and representatives of the fertilizer and pesticide industries. Similar evaluations for the North Central and Northeast projects given in the 1991 report provided guidance for this year's activities.

Abstracts for the two types of research projects of the water quality program, the Priority Components and the Selected Geographic Systems--Management Systems Evaluation Areas (MSEA) are included in the appendices of the comprehensive reports. These concise abstracts report progress of research inspired and funded in part by the President's Initiative program of ARS and CSRS. It is apparent that several of the awards "bought into" ongoing research projects yielding quicker results for use by agricultural producers. Outstanding research is underway in both programs. Onsite reviews of the MSEA projects in 1991 produced recommended changes implemented in 1991 and 1992. Adoption of results from the five major MSEA projects in the Midwest is essential. Researchers are working with education and technology transfer specialists to achieve this goal.

Interactions among meeting participants were useful from a program management view, as well as to communicate research progress and roadblocks. The significant accomplishments achieved during the past two years, and the knowledge developed through future research, will greatly enhance our understanding of fate and transport of potential contaminants in soils and water. And, these accomplishments will facilitate the adoption of economical and environmentally acceptable agricultural production systems to avoid or reduce pollution and enhance surface and groundwater quality.



Charles B. Rumburg
Deputy Administrator
Natural Resources, Food and Social Sciences
Cooperative State Research Service



Dale A. Bucks
National Program Staff
National Program Leader, Water Quality
Agricultural Research Service

Co-Chairs, Water Quality Research and Development Committee
USDA Working Group on Water Quality

WATER QUALITY RESEARCH: THE PRESIDENT'S INITIATIVE PROGRAM REVIEW AND EVALUATION, 1992

South Region, Baton Rouge, Louisiana

BACKGROUND

The deterioration of water quality or the potential for it, resulting from the use in agriculture of certain pesticides, fertilizers, manures, and sludges, is a problem of major concern to rural and urban people and scientists. The development of effective and economically feasible technologies that avoid excessive concentrations of potential contaminants, or remediate problem conditions, requires a comprehensive understanding of what happens to chemicals and other products in soils and water and the appropriate application of information. Research in agriculture was given major impetus by new emphasis on water quality in the statement of an Initiative by The President.

"The protection of the environment and the conservation and wise management of our natural resources must have a high priority on our national agenda. But given sound research, innovative technology, hard work, sufficient public and private funds, and--most important of all--the necessary political will, we can achieve and maintain the environment that protects the public health and enhances the quality of life for us all." *President George Bush*, "Building a Better America," February 9, 1989. This document also gave three principles as the basis for the Initiative, as follows:

- "The President is committed to protecting the Nation's groundwater resources from contamination by fertilizers and pesticides without jeopardizing the economic vitality of U.S. agriculture.
- "Water quality programs must accommodate both the immediate need to halt contamination and the future need to alter fundamental farm production practices.
- "Ultimately farmers must be responsible for changing production practices to avoid contaminating ground and surface waters. Federal and state resources can provide valuable information and technical assistance to producers so that environmentally sensitive techniques can be implemented at minimum cost."

WATER QUALITY RESEARCH OBJECTIVES

The objectives are from two sources.

USDA Research Plan for Water Quality, January, 1989

1. Document the sources and amounts of potentially hazardous contaminants in groundwater which are attributable to current agricultural and forestry practices, and identify the basic processes involved in their movement through soil and into groundwater.
2. Develop new field and laboratory methods for rapidly, reliably, and inexpensively analyzing pesticide residues and for determining the rates at which water and chemicals move through soils to groundwater.
3. Develop new and modified crop and livestock production systems that substantially decrease the movement of potentially hazardous chemicals into groundwater, and determine the effects of these new systems on farm costs, changes in farm inputs, and production choices.
4. Develop simple, inexpensive, on-farm methods for disposing of pesticide containers and other hazardous wastes without contaminating groundwater.
5. Develop decision-aid systems that may be used by technical and farm management specialists, Extension agents, and farm consultants to help individual farmers select, apply, and manage profitable and environmentally sound crop and livestock production practices.
6. Evaluate economic, social, and political impacts of alternative crop and livestock production systems, policies, and institutional strategies to control groundwater contamination.

USDA Water Quality Initiative 1992 Work Plan

1. To improve and expand our knowledge of agricultural practices related to water quality.
2. To integrate that knowledge into production management systems that use economically and environmentally sound practices.

Program evaluation, to be accomplished through reporting and planning conferences, was specified in the USDA Research Plan for Water Quality (1989), the Water Quality Program Plan to support the Initiative (1989), and the USDA Water Quality Initiative Work Plans for 1990, 1991, and 1992.

All projects supported by initiative funding are considered as a total program of interrelated water quality research. The U.S. Department of Agriculture (USDA) Research Plan for Water Quality (1989) set up a structure with two general types of research activities. One type designated as Priority Components research includes a wide range from fundamental laboratory and field research to applied types of technology-driven studies, concentrating on parts or "components" of processes, practices, or systems. The other type in the 1989 Plan, Selected Geographic Systems, is represented by the long term Management Systems Evaluation Areas (MSEA) begun in 1990. This research focuses on developing and evaluating agricultural production systems for corn and soybean production areas, and is comprised of feasible combinations of results from components research, other relevant studies, and practical experience.

There are two reports resulting from the 1992 evaluation and planning sessions for the South and West Regions held at Baton Rouge, Louisiana and Tucson, Arizona, respectively. Also, a separate summary of accomplishments is available. Abstracts of the past year's research results for all new and continuing Water Quality Initiative projects funded by ARS and CSRS are included in the Appendix. All of this information was considered in the evaluation of progress and the research needs and priorities given in this report.

PRIORITY COMPONENTS

INTRODUCTION

The water quality research program review and evaluation of accomplishments and needs, funded as USDA grants and awards under the President's Initiative, was participated in by federal, university, industry, and independent scientists, 6 evaluators at each location, several observers, and speakers. There was a total of 159 projects of the Agricultural Research Service (ARS), Cooperative State Research Service (CSRS) and State Agricultural Experiment Stations (SAES), and collaborators, that constituted the accelerated and new water quality program being evaluated. In addition to these agricultural research organizations, participation included the Extension Service (ES), Soil Conservation Service (SCS), U.S. Geological Survey (USGS), the fertilizer and agricultural chemicals industries, and the private sector. Additional participants were invited.

EVALUATION and WORKSHOP OBJECTIVES

Exchange scientific and technical information among principal investigators, other researchers, program managers, and users of information.
Evaluate progress, collaboration, and coordination in USDA-funded research programs.
Identify significant results and new developing opportunities for collaboration with related programs.
Identify promising agricultural production and management systems and technologies.

PLAN and PROCESS

States in the Southern and Western Regions were involved in the April 21 to 23, and April 28 to 30, 1992 evaluation and review conference at Baton Rouge and Tucson, respectively. Principal investigators of all projects receiving Initiative funding in FY 1990 and 1991, and ongoing projects from FY 1989, were requested to prepare an abstract and report of progress, display and discuss a poster of research results and future plans, and participate in a work group(s). They discussed accomplishments and cooperatively developed priorities for problems still needing solutions, considering the goals and objectives of the Initiative. In addition, scientists in the North Central and Northeast Regions who received Initiative funds also prepared abstracts and progress reports. All abstracts were available for the 1992 meetings. They appear in the appendices of the comprehensive reports; titles and investigator names are in the appendix of the Summary report.

The scientists at the two workshops were organized into general Research Problem Area (RPA) work groups to reflect their interests and expertise, including: Chemical Fate and Transport; Transformation and Remediation--Pesticides, other Organics and Microbes; Nitrogen, other Nutrients, Wastes, and Metals; Production Management Systems; Social Sciences; Education and Technology Transfer. The last two groups interacted with each of the other four RPAs. The Education and Technology Transfer group included "users" of information representing ES, SCS, the private sector, industry, and several participants from other panels. Recommendations by the workshop panels will be utilized by CSRS and ARS in setting priorities for funding water quality projects in FY 1993 and later years.

An Evaluation Panel composed of an expert in each RPA was selected from outside the region being evaluated, except for the Social Sciences RPA in the South and the panel leaders for Education and Technology Transfer. The evaluation panelists were responsible for reviewing abstracts and reports by the scientists and other materials prepared for the meetings, and for the preparation of a report given at the beginning of the meeting. This served as the baseline for scientist debates within the individual workshops. The evaluation panelists prepared reports of the deliberations and conclusions of their respective workshops. These became the individual RPA reports.

Evaluation Panel and Work Group Guidelines

The evaluation included examining several aspects of the development of the research, whether it addresses appropriate problems in water quality, progress of the overall program, interactions with others, usefulness of results, and other points. The following guidelines were presented.

Appropriate development of program objectives and plans,
Use of the most technically advanced methods in research,
Interdisciplinary, inter-site, and inter-agency coordination where appropriate,
Adequacy of results to determine if water quality can be protected/enhanced, and how to do it,
Transferability of results or methodologies to--
Education and technical assistance agencies, consultants, and farmers,
Other areas and regions of the country, and
Other management conditions in time and space.
Identify research needs and opportunities that need a different emphasis to facilitate meeting program objectives, and
Suggest changes of emphasis to meet the needs.

EVALUATION and WORKSHOP RESULTS

The Initiative program has funded excellent research at a number of Land Grant Universities, ARS laboratories, and private foundations. The principal investigators are well qualified, the overall quality of research is high, and the projects address a broad range of problems from both a subject matter and geographic viewpoint. The investigators are using "cutting edge" analytical and experimental methods. Numerous projects have made advances that can have an immediate impact on enhancing groundwater quality.

The scientists' reports for the program evaluation were based on only 6 to 24 months of results from 2- or 3-year projects funded by the President's Initiative on Water Quality. Movement and degradation of pesticides is usually a long-term problem, the solution of which requires an investment in long-term research activities. The research reported here utilized fundamental and applied methods to learn about the behavior of pesticides in soil and water. Emphasis was on widely used chemicals or ones having been detected in groundwater.

Details of work group actions are given in reports of the South and West. They contain program evaluation information and recommendations of research needs that may require special attention. Also, certain problem areas are recommended for increased emphasis to reflect the impact of research already underway. Conversely, some types of research have sufficient results to justify a redirection of emphasis.

STATE OF COMPONENTS RESEARCH

INFORMATION CONTAINED IN THIS REPORT IS CONSIDERED PRELIMINARY AND THE PRINCIPAL INVESTIGATORS SHOULD BE CONTACTED FOR DETAILS AS TO INTERPRETATION AND USE.

The processes by which chemicals used in agriculture reach surface and groundwater range in space and time from microscopic to fields and watersheds and from seconds to days and decades. Studies of these orders of magnitude require a well conceived and long-term research program. The USDA research awards have contributed to progress in solution of a broad range of problems. Much of the emphasis has been on those where short-term research was expected to yield good information.

One of the most significant accomplishments of the Water Quality Initiative is graduate student and post doctoral training. This is emphasized in several of the work groups as being an important spinoff that generates intensely trained students in broadly diverse areas--all very important to our concerns about protecting and maintaining quality of our natural resources.

To aid in understanding the technology transfer (TT) concept and to convey a classification of accomplishments from the research being evaluated, the results given under each RPA were classified as to phase of technology transfer. We have used the phase designations and explanations given by R. S. Rauschkolb¹, panel member for TT at the Tucson meetings. "Technology transfer occurs along a continuum of development and application from the initial concept of the hypothesis to final application and adoption by the practitioner. Even the most basic scientist is a benefactor of technology transfer." The status of accomplishments is identified by TT-phase to more readily assess the contribution of the accomplishments toward some perceived solution to a problem. The term technology is used in a broad sense to include information and knowledge transfer to scientists, specialists, producers, policy makers, and others.

- Phase 1. Results of research are ready for sharing with the scientific community and are presented for verification of the principle, methodology or technique.
- Phase 2. Results are ready for development and adaptive research through field validation in collaboration with scientific colleagues in Extension, Industry, SCS, *et al.* The principle is being adapted and used under a wide range of conditions in order to collect the data required to conduct an educational program to facilitate adoption in phase 3.
- Phase 3. The practices, methods, or techniques are ready for widespread implementation and commercial adoption.

¹ Rauschkolb, R. S., and L. W. Dewhirst. 1991 Technology Transfer: A University Perspective. p. 167-184. In V. J. Rhodes (ed.) Agricultural Sciences Policy in Transition. Agricultural Research Institute Publ., Bethesda, MD.

Fortunately, proposals were conceived that built upon accomplishments of earlier relevant research, and extended ongoing projects where additional funding would produce quicker or more useful results. *The Initiative program has facilitated integration of results into products for immediate application as well as a more focused assessment of remaining problems.*

Within each RPA under the subsection titled "State of Current Research", some products of the individual research projects funded by ARS and CSRS are given. The technology transfer phase (TT-_) classification and the state(s) where research was done are given for each product or accomplishment. The TT phase establishes the listing order for the accomplishments, with phase 1 given first. Where two numbers are given, the results are at different stages of development for conditions of climate, soils, chemicals, etc., which affect those results or the adoption of them.

CHEMICAL FATE AND TRANSPORT

Fate and transport processes to which chemicals are exposed as they travel from soil surface to groundwater are imbedded in nearly all projects funded under the general Research Problem Area (RPA) of the water quality program. They include microbial degradation, sorption and desorption, precipitation and dissolution, and transformation to gaseous compounds. The study of these processes requires application of physics, chemistry, microbiology, mathematics and computer science.

The space and time scales of the processes by which surface applied chemicals reach groundwater range from microscopic to watersheds and from seconds to decades. Clearly, these studies require an ongoing and long-term research program. With this background, we note that the USDA research awards, with an emphasis on short-term results, have made strong contributions toward progress.

The research funded by the USDA Water Quality Program drawing from the accomplishments of earlier research has forced integration of results into products for immediate application as well as a more focused assessment of remaining problems. The progress and products of the individual research projects are summarized in this report, and remaining needs are also stated.

The USDA Program Objectives specifically focused on fate and transport are:

USDA Research Plan for Water Quality, 1989--Objectives 1 and 2

USDA Water Quality Initiative, 1992 Workplan--Objective 1

State of Current Research

Preferential (by-pass) flow. Relationships have been defined between the magnitude of by-pass flow and basic soil properties. Research has identified and is continuing to identify soils in which preferential flow is significant. Results provide the possibility to incorporate the mechanism of preferential flow into water and chemical transport models, thereby making these models more realistic and useful. (AR, KY, SC) [TT-1]

Hydrologic characteristics of soils. Progress has been made with development of a soil classification system based on the soil characteristics which control water and chemical transport through soil. The classification system accounts for those soils with uniform flow as well as those that exhibit preferential flow as a result of structural characteristics, shrink-swell planes, or layered soils. The system will be used to identify soils and landscape units most vulnerable to groundwater contamination. (AR, KY, SC) [TT-1]

Transport through partially weathered rock. Efforts are underway to characterize the transport of water and chemicals through strata between the plant rooting zone and groundwater, i.e., saprolites or partially weathered bedrock, with emphasis on evaluating suitability of use for disposal of household wastewater in rural areas. The information being developed provides the data needed to link root zone and groundwater data sets and transport models. (NC) [TT-1]

Water quality of Karst systems. Temporal variations in chemical concentrations of water moving through Karst topography are being measured. Measurements on undisturbed formations will be used as a baseline to help define the effects of human activities on chemical contamination of water in Karst springs. Data are also being collected which help to partition chemicals in spring water between those which entered the flow system from a sinkhole and those which entered from the soil that surrounds the conduit. (KY) [TT-1]

Manure application to land. A mathematical model has been developed for simulation of fate and transport of nitrogen compounds resulting from application of poultry litter and manure to agricultural fields. It incorporates those variables that affect surface runoff, volatilization, plant uptake, and leaching. The model can be used throughout the Southern Region to aid in land application strategies that reduce ground and surface water contamination. (AR) [TT-2]

Transport model GLEAMS. A nutrient transport component for nitrogen (N) and phosphorus (P) has been added to the GLEAMS model, thus expanding its usefulness for management of fertilizer and manure applications. (GA) [TT-2]

Water quality of loess soils. Water quality in loessial deposits in Arkansas, Kentucky, Louisiana, Tennessee, and Mississippi can be improved by adoption of no-tillage practices in combination with winter cover crops without increasing the movement of nitrate-N below the root zone or increasing groundwater vulnerability. The finding is noteworthy and important because it contradicts earlier assessment of no-tillage practices. (TN) [TT-2]

Water quality of Coastal Plain watersheds. Researchers have described and measured the nitrate-N and pesticide contaminant problems in surface and groundwater in several coastal plain watersheds, particularly where animal production facilities are concentrated. Riparian zones and vegetated buffers can be used effectively to reduce concentrations of chemicals in surface and groundwater leaving these watersheds. (GA) [TT-2]

Water table management. Water table management by means of controlled tile drainage has been shown to be an effective practice for reducing surface runoff (>50%), nitrogen and phosphorus losses (>30%), and pesticide losses (>50%) in poorly drained soils. When water table management is combined with fertilizer and pest management practices further reduction in losses of these compounds is obtained, e.g., aldicarb loss is further reduced by a factor of two. (NC, LA) [TT-3]

Transport and fate on N and pesticides predicted. The USGS model US2DT was modified and tested for predicting the movement and fate of N and pesticides in areas with subsurface tile drainage for control of the water table. (NC) [TT-3]

Research Needs and Opportunities

The working group suggested the following to be high priority research needs.

Mass balance determinations. Establish a mass balance for all studies of fate and transport conducted at scales from pedon to watershed. This is needed to fully quantify all mechanisms involved in fate and transport. This would facilitate reliable long-term predictions of accumulation of chemical or biological species of concern at various points along their travel path in a watershed.

Expected result. Emphasizes to investigators the need to account for all processes involved in fate and transport; imposes quality control and quality assurance; assures more complete final product.

Microbial rate processes. Determine rates of microbial transformations along the travel path of potential contaminants from the soil surface through the root zone, the unsaturated zone below root zone, and the saturated zone, for organics (pesticides, herbicides, plant material) and nitrogenous compounds, as a function of space and time. Microbial process rates vary as functions of characteristics of the microbes, position in the profile, time of year, climate, and flow rate of water. Precise determination of these functions is required for evaluation of cropping strategies using mathematical simulation models and more qualitative assessments.

Expected result. Eliminates remaining uncertainties regarding the role of microbial rate processes; provides information needed for extrapolation of results; improves the ability to relate desired regulation end points with management practices.

Role of riparian zones. The functions of vegetated riparian zones needs to be established in detail. Current assessment of their function and value in the management of water quality is based on incomplete and often qualitative knowledge.

Expected result. Completes knowledge about function of riparian zones for water quality management; provides information required for design of management practices, including riparian zones.

Improve problem identification. Identify and document the magnitude of contributions of agricultural practices to contamination of surface and groundwater throughout the South, and identify the major fate processes and pathways of transport.

Expected result. Improves problem identification which remains extremely incomplete due to large differences in combinations of geographic zones and climatic zones; more complete problem identification would assure better targeting of management practices.

Validate simulation models. Strengthen efforts to validate simulation models of fate and transport specifically for application to individual fields and at the watershed scale.

Expected result. Validation for the expected range of environmental conditions assures the ability to use models for designing management practices matched to desired regulation end points.

Bypass flow. Quantify the role of bypass (preferential) flow for important combinations of soils, rainfall frequency, storm duration and amount, soil temperature, and tillage methods. The rate of bypass flow with respect to leaching of soil surface applied substances is known and understood only in a conceptual manner. Information which can be used in a predictive manner is required.

Expected result. USDA supported research has only recently revealed the importance of bypass flow, a designation which describes high rates of leaching in some parts of the soil profile and very low rates in others. *The traditional view of a uniform soil with constant physical, chemical and biological properties throughout the soil profile is thus clearly not valid.*

**** NEARLY ALL CURRENTLY USED DESCRIPTIONS AND MODELS IGNORE BYPASS FLOW PHENOMENA AND THEIR CONSEQUENCES.** Further study of mechanisms underlying bypass flow will provide information needed to make analysis of fate and transport more realistic at the field scale and to provide reliable predictions for proposed or current management.

Microbial processes in soils with bypass flow. Comprehensive experimental and theoretical analysis of rate of microbial processes in soils with pronounced bypass flow must be initiated. Nothing is known about the spatial and temporal distributions of compounds subjected to a bypass flow system at the scale of microbial processes. This is a problem of substrate availability, microbial density in the soil, and by-product removal.

Expected result. Combines knowledge gained about microbial rate processes and bypass flow, thus making it possible to develop and validate models for predicting pollution potential associated with farming practices. Also, the results would be used in analysis of the potential for engineered organisms to mitigate or clean-up contaminated areas.

Linkage between agronomic practices and regulations. Establish linkages between agronomic practices and regulations. Define conceptual cropping systems utilizing substantially reduced rates of fertilizers and/or pest control chemicals, and analyze these systems in terms of contributions of substances to vadose zone water and groundwater. Determine yield potential and feasibility of these systems. This approach must be taken for all important production areas.

Expected result. Provides establishment of functional relationship between regulation and agronomic practices; assures application of fundamental knowledge developed under prior research projects.

Properties of substrata below root zone. Determine physical, chemical, and hydrological properties of the subsurface below the root zone, e.g. saprolites, fractured rock. This important component of the flow path is incompletely described and understood.

Expected result. Fills in remaining knowledge gaps regarding the medium below the root zone. Provides sanitary engineers, county planners and others participating in design and operation of septic tanks for individual rural homes or groups of homes, with the needed design information. Improves reliability of life expectancy prediction of septic systems.

When and where to sample. Establish reliable relationships between point measurements in time and space and the watershed mass balance of chemicals.

Expected result. Determines the relationship between actual contaminant concentration distributions in the soil and subsoil, and results from analyses of samples by means of point sampling using a sparse data network.

Program Management Recommendations

Broaden meeting attendance. Some suggested that, if practical, all principal investigators (P.I.) should be urged to participate in evaluation meetings, in addition to the project director. This would give better representation for multi-state projects.

Scientist presentations. The question of oral presentations of achievements in each project during the first group meeting was discussed. Such presentations would either replace the posters, which were well done and very useful, or result in a much longer meeting.

Integrated systems emphasis. Increase emphasis on integrated systems to facilitate adaptation of the results through development of technology transfer within each project.

Work Group Participants

<u>Name</u>	<u>Institution</u>
A. Amoozegar ¹	N. Carolina State Univ, Raleigh, NC
D. D. Bosch	ARS-USDA, Tifton, GA
L. Boersma ²	Oregon State Univ, Corvallis, OR
C. R. Camp	ARS-USDA, Florence, SC
M. J. Cochran	Univ of Arkansas Fayetteville, AR
T. C. Daniel	Univ of Arkansas, Fayetteville, AR
G. K. Felton	Univ of Kentucky, Lexington, KY
R. Johnson	ARS-USDA, New Orleans, LA
J. McInnes	Texas A&M Univ, College Station, TX
Armand Pepperman	ARS-USDA, New Orleans, LA
R. E. Phillips	Univ of Kentucky, Lexington, KY
V. L. Quisenberry ³	Clemson Univ, Clemson, SC
J. S. Rogers	Louisiana State Univ, Baton Rouge, LA
H. D. Scott	Univ. of Arkansas, Fayetteville. AR
R. W. Skaggs	N. Carolina State Univ, Raleigh, NC
G. Willis	ARS-USDA, Baton Rouge, LA
G. V. Wilson	Univ. of Tennessee, Knoxville. TN
Dale Bucks (ARS) and Berlie Schmidt (CSRS) participated and rotated among RPA sessions.	

1A. Amoozegar, Recorder for Work Group

2L. Boersma, Evaluation Panel member

3V. L. Quisenberry, Chair of Work Group

TRANSFORMATION AND REMEDIATION

Pesticides. Other Organics. Microbes

Research projects in this general RPA could be under other specific RPAs; however, to date in the South, projects were funded in only three: fate of pesticides; application technology; and bioremediation methods. While the projects that were funded are excellent, they only represent a small fraction of the research needed as identified in the USDA Research Plan for Water Quality, 1989, and in the USDA Water Quality Initiation, 1992 workplan. The next step for some of the research results is technology transfer, whereby the information will be put to general use.

Research funded under this general RPA of the water quality program addresses the USDA Program Objectives as follows:

USDA Research Plan for Water Quality, 1989--Objectives 1, 2, 4

USDA Water Quality Initiative 1992 Work Plan--Objective 1

State of Current Research

Subsurface drains in sugarcane culture have been used to collect soil leachate containing up to 100 times the health advisory levels of atrazine concentrations at certain times of the year. The use of subsurface drains to minimize the potential for pesticide leaching to groundwater can be effective but may raise the question of disposal. (LA) [TT-1]

Inexpensive adsorbents for pesticide rinsate and waste solutions have been developed for quickly reducing pesticide solution concentration from over 1000 ppm to levels for release of waste water. This addresses only one-half of the problem. Methodology is being developed for disposal of concentrated adsorbed pesticide waste. (AR, VA) [TT-1,2]

Ultra-low-volume herbicide use and sensor sprayers. Methods have been developed, and are now available for use, to reduce the amount of herbicide applied to control weeds using ultra-low-volume (ULV) and sensor sprayers. ULV can reduce application rates of postemergence herbicides by a factor of 10, and sensor sprayers only treat weeds detected by the sensors. (MS) [TT-2, 3]

A minimal potential to leach to groundwater under normal agricultural practices has been shown for fenamiphos, a nematicide for turfgrass, and fluometuron, a herbicide used in cotton production, due to rapid degradation, sorption, or a combination of the two processes. Based on the results of research, fluometuron can be used to provide weed control without adverse effects on water quality. (FL, MS) [TT-2]

Research Needs and Opportunities

The four highest priority areas resulting from the working group discussions were: Basic research on processes impacting pesticides; application technology to reduce pesticide use; model validation/use in decision aids; and bioremediation, examples of which are given. It was noted that before any pesticide research can be done analytical methods must be available, which may not be the case for some of the newer herbicide chemistries.

Analytical Methods

Develop analytical methodology for research on newer classes of herbicide chemistries that are applied at ultra low volume (ULV) rates, including decreased detection levels and cost.

Expected result. Analytical methodology will not be a limiting factor in pesticide research.

Basic Processes

Characterize chemical, physical, and biological properties of subsurface soils that affect pesticide degradation. For instance, characterize subsurface soil microbiology especially ecology, activity, population dynamics of pesticide degrading microorganisms, and methods to stimulate populations or degradative activity. Also, determine clay mineralogy and organic carbon content of subsurface soils to characterize pesticide sorption which in turn controls degradation.

Expected result. This research will provide missing information needed to understand requirements of microbes expected to degrade pesticides once they move out of the surface soil, the soil zone of most previous research on pesticide degradation.

Develop a database on biodegradation and sorption potential of different surface and subsurface soils for a variety of pesticides.

Expected result. Results can be used to develop leaching indices for pesticides and for pesticide transport models that can be used for predictive or regulatory purposes.

Application Technology

Perfect technology to reduce rates of pesticides used for pest control. Additional research is needed in ULV postemergence application and reduced rates in preemergence applications.

Expected result. Reduction in pesticide loading rates will, in turn, reduce amounts of chemical that potentially can move to groundwater.

Determine impact of formulation on pesticide leaching in soil. Research is needed on controlled release formulations that reduce leaching while maintaining efficacy, and whether additives such as adjuvants, surfactants, etc. increase leaching.

Expected result. Use of appropriate formulations can reduce potential movement of pesticides to groundwater.

Develop a direct-injection system that can eliminate leftover pesticide solutions and pesticide rinsate problems.

Expected result. Results of research will provide a possible solution of what to do with pesticide waste solutions/rinsates, a potential point source of groundwater pollution.

Model Validation/Decision Aids

Couple data needed for model validation, including data on crop, weather, soil, and pesticide, to field experiments on fate and persistence of pesticides.

Expected result. Field experiments on pesticide fate are very expensive. If data needed for model validation are obtained along with pesticide data, development of solute transport models will be facilitated.

Develop an expert system that enables farmers to select herbicides on the basis of crop, soil, and herbicide characteristics, leaching potential, cost, and risk.

Expected result. This would allow a farmer to make better decisions and obtain economical weed control while protecting water quality.

Bioremediation

Removal of pesticides from rinsate or waste solutions. Systems should be further perfected and evaluated for effectiveness, cost, and practicality. Chemical conversion to nontoxic products, degradation by organisms from genetically engineered or isolation-enrichment techniques, or concentration on solid sorbents that can be easily disposed of are promising systems.

Expected result. Research will provide practical technology to eliminate potential point sources of pollution.

Program Management Recommendations

Prioritize pesticides to be studied on a regional basis--for example, the South.

Decrease priority for funding research on atrazine, alachlor, and metolachlor for corn production. The MSEA in the Corn Belt states are concentrating on these, and such action would force people to consider alternative chemicals for study.

Increase priorities of research on newer chemicals used in weed control.

Pesticide efficacy research on high priority targets should be required as part of any proposed study on ULV (reduced rate) pesticide fate studies.

In alternate years, design national program review and evaluation workshops by RPA, rather than having all RPAs by region.

Modify RFP and award decisions to reflect a higher priority on basic processes involved in research on fate of pesticides in soil and water.

Have select panel of scientists meet to develop a more focused RFP based on the highest priority research needs prior to RFP being prepared.

Devise alternative scheme so funds to be competed for are assigned by RPA. Some RPA may generate fewer proposals but have higher priority problems. Also, pesticide fate research is more expensive than N fate research. Consider in detail the costs of different types of research in making awards.

Work Group Participants

<u>Name</u>	<u>Institution</u>
Duane F. Berry	VPI&SU, Blacksburg, VA
James Hanks	ARS-USDA, Stoneville, MS
Arthur G. Hornsby	University of Florida, Gainesville, FL
Richard M. Johnson	ARS, SRRC-USDA, New Orleans, LA
Chuck Kenerley	Texas A&M Univ, College Station, TX
Bill Koskinen ¹	ARS-USDA, St Paul, MN
Terry Lavy ²	University of Arkansas, Fayetteville, AR
Joe Massey	University of Arkansas, Fayetteville, AR
Chester McWhorter	ARS-USDA, Stoneville, MS
Tom Mueller	University of Tennessee, Knoxville, TN
Pat Norris	Oklahoma State Univ, Stillwater, OK
Eric Osborn	Texas A&M Univ, College Station, TX
Li-Tse Ou	University of Florida, Gainesville, FL
Armand Pepperman	ARS, SRRC-USDA, New Orleans, LA
Magdi Selim	Louisiana State Univ, Baton Rouge, LA
Lloyd Southwick ³	ARS-USDA, Baton Rouge, LA
John E. Thomas	University of Florida, Gainesville, FL

1W. C. Koskinen, Evaluation Panel Member

2T. Lavy, Work Group Recorder

3L. Southwick, Work Group Chairman

NITROGEN. PHOSPHORUS. WASTES. METALS

Research in the Southern region funded under the water quality initiative included work on: irrigation and drainage water management; remediation of contaminated soils and water; and agricultural management and water quality. All of the research projects in this RFP investigated reduction of nitrate flow from agricultural lands to groundwater or reduction of nitrate and/or phosphate flow to surface water.

The abstracts and brief research reports summarized eight research projects from the Southern region that are underway. They appeared to be excellent and contributing to the objectives of the water quality research program. Discussions with the scientists doing the research confirmed this conclusion. Poster presentations by the scientists were excellent and very helpful in explaining in more detail the investigations and how they may solve water quality problems.

It was evident from the poster presentations that work was integrated with other subdivisions of this review, in particular fate and transport. This strongly emphasizes the close link between movement of water, nutrients and pesticides. It is also clear that the Southern region has great diversity ranging from areas of very low rainfall in regions of Texas and Oklahoma to the high rainfall areas of the Coastal Plains.

The USDA Program Objectives addressed in this RPA are:

USDA Research Plan for Water Quality, 1989--Objectives 1, 3, 5, 6

USDA Water Quality Initiative, 1992 Workplan--Objectives 1, 2

State of Current Research

Heavy applications of poultry, dairy, and swine waste can produce water pollution.

Nitrate leaching is both a short term and a long term problem, involving characteristics of the manure, handling, soils, and costs associated with land disposal at various distances from the source. Levels well over 100 mg N/liter (ppm) have been measured in groundwater under

heavily manured areas. While research has generally shown that use of best management practices controls nitrate losses, they are not being rapidly adopted by producers. State regulations are forcing compliance in many of the states. (AR, VA, GA) [TT-1, 2]

P build-up from over-application of animal waste to the surface of the soil resulted in movement of soluble and bioavailable P into surface waters. Although this movement could be rather accurately modeled, control of P from waste was not feasible when the customary practice of "amount of nitrogen (N) applied" was the criterion used to limit manure application rates. (AR, confirmed by VA, GA) [TT-1, 2]

Best management practices to reduce nitrate leaching have included soil nitrate tests and/or some tissue analysis to improve N fertilizer recommendations. There has been limited success with N soil testing in the humid areas; whereas, nitrate soil testing is well established in drier areas of the Great Plains and the West. (VA) [TT-1], & (OK, TX) [TT-2, 3]

N use efficiency has been improved by timing of nitrogen application to crops. Two practices were shown to work in the Coastal Plains area: (1) fertigation (N applied in irrigation water) maintained production with less fertilizer application as compared to conventional preplant fertilizer applications; (2) split application of N on non-irrigated areas resulted in less nitrate leaching and hence a lower fertilizer requirement to maintain productivity. (GA) [TT-2]

N and P runoff losses in drier areas of Oklahoma were also decreased with cover crops, but runoff losses of soluble P and bioavailable P sometimes increased. (OK) [TT-2]

Water table management reduced loss of nitrate when water tables were kept high as compared to freely drained treatments. (NC, SC) [TT-2, 3]

Reduction of residual nitrate has been accomplished by using cover crops. In addition to rye, winter wheat and barley have been used to reduce soil erosion, while canola, oats and forage turnips were shown to remove large quantities of residual nitrogen. (GA) [TT-3]

Nitrate from animal waste drained into playas did not leach. The evaluation of nitrate movement below "playa's" that have stored beef cattle feedlot runoff for more than 20 years showed less than 3 mg N/kg (ppm) as nitrate below one meter depth showing that they function well in containing nitrate from animal waste. (TX, OK) [TT-3]

Modeling was not the primary focus in any project, but a phase of several projects included use of models to aid the researcher in meeting objectives, to improve predictability of processes, or to transfer technical knowledge to user groups.

Summary of Accomplishments

Problem. Nitrate levels in shallow groundwaters in the Coastal Plains area of the South are commonly 15 to 20 mg N/liter, well above the drinking water standard of 10 mg N/liter.

Results.

Cover crops after harvest of the agronomic crop will reduce the quantity of nitrate flowing to groundwater. Canola, oats, and forage turnips in addition to more commonly used rye, winter wheat and barley have been shown to be effective in lowering nitrate levels in soils. Over 100 pounds N/acre has been captured in cover crops. The use of cover crops for erosion control is well established so the extension of this technology and possible change in crops to remove more nitrate is feasible and may reduce nitrate losses in a large acreage of the humid region. [TT-3]

Improvement of existing riparian zones and establishment of new riparian zones have been shown to reduce nitrate levels in shallow groundwater by denitrification and by plant uptake of nitrate. Increased use of this technology can potentially reduce nitrate levels to acceptable levels before the shallow groundwater emerges to streams and estuaries. [TT-2]

Water table management has been shown to reduce nitrate losses in tile drained soils in North Carolina and South Carolina. This technique is potentially applicable to a large area (>10 million ha) in the Southern region. Validation and demonstration may be necessary in other states before it will be adopted in those areas. [TT-2,3]

Problem. Productivity of agronomic crops must be maintained through greater N use efficiency in high rainfall areas, thus less leachable residual nitrate.

Results.

Fertigation improved N use efficiency; reduced losses of nitrate by leaching. [TT-2, 3]
Split application of N fertilizer for a crop has been refined as a best management practice for non-irrigated lands. This practice has been shown to reduce nitrate leaching. [TT-2, 3]

Research Needs and Opportunities

The animal industry is in a critical period. Large animal operations have utilized land disposal of manures and waste because it has been economical. But the potential for nitrate leaching and a rapid increase in soluble and extractable P in soils receiving animal waste threatens to curtail these industries. The future priority research in this RPA must address this critical problem. Recommended research needs are in three broad areas: animal waste, nutrient management, and modeling. The specific needs listed under each area should receive emphasis beyond the on-going research in water quality.

Animal Waste

The limits of P loading from animal waste, before runoff losses to surface waters reach unacceptable levels, is urgently needed information. Also there should be a standardized test to evaluate soil P loading.

Expected Result. Establishment of these limits will identify specific areas and causes of P enrichment of surface waters. Control measures can then be put in place.

"Release coefficients" for N are needed from manures and residues for both legumes and non-legumes.

Expected Result. With these release coefficients more precise credits may be given to these nutrient sources when making recommendations for nutrient applications from all sources.

Determine the best cropping systems and management practices to use in conjunction with heavy animal manure applications.

Expected Result. An improved ability to utilize nutrients from animal manures with minimum loss to surface or groundwaters.

Nutrient Management

Control of nutrients and water to optimize crop production and minimize loss of nitrate to groundwater.

Expected Result. Refinement of nutrient and water use to maintain productivity of agronomic crops and minimize environmental contamination.

Perfect technologies for precise nutrient applications based on soil type and spatial variability, so optimum production may be obtained with minimum movement of nitrate to the groundwater and P to surface waters.

Expected Result. Improved nutrient and water utilization in agronomic crop production and reduced loss of nutrients to groundwater or surface waters.

Document and evaluate the economic feasibility of improved water management in more states of the Southern region, including irrigation and controlled water tables, to reduce losses of nitrate, other nutrients and pesticides.

Expected Result. This should reduce nutrient losses and expand application of the work developed in North Carolina.

Modeling

Emphasize refinement, modification, integration and validation of current models to improve their utility. Effective models are needed for field and watershed scales.

Expected Results. Development of appropriate models will improve management and help predict weak points in agronomic and animal production that affect water quality.

Metals and other toxic ions were not included in any of the eight projects. In the Southern Region, contamination of groundwater by metals is largely from point sources resulting from industrial spills or waste. There are a few documented cases of groundwater contamination with potentially toxic ions. For example, Texas has reported arsenic contamination of groundwater resulting from improper handling of arsenic acid and from waste piles of cotton burrs that have

accumulated arsenic during production. Since these are isolated point sources of contamination, in this region research into the cause and clean-up should have a low priority in the President's Initiative program.

Agricultural land may be utilized for recycling nutrients from municipal sewage sludges, composted sludges, and industrial waste. Although sludges generally are applied to crops based on the quantity of N they contain, metals may also be included in quantities that can be detrimental. Prior research by USDA-ARS, and agricultural experiment stations has established limits for metal loading for Cd, Pb, Zn, Ni, Cu and perhaps others. Following the recommendations from this research leads to safe utilization of by-product sludges and other waste materials and protects both groundwater and surface water. For this reason, further research on metal applications should have a low priority in this President's Initiative Water Quality Program.

Work Group Participants

<u>Name</u>	<u>Institution</u>
D. Albrecht	Texas A&M, College Station, TX
M. Alley	Virginia Tech, Blacksburg, VA
T. C. Daniel	Univ of Arkansas, Fayetteville, AR
B. G. Ellis ¹	Michigan State Univ, E. Lansing, MI
J. L. Fouss	ARS-USDA, Baton Rouge, LA
B. L. Harris	Texas A&M, College Station, TX
J. Hook ²	University of Georgia, Tifton, GA
B. Hubbard	ARS-USDA, Tifton, GA
P. G. Hunt ³	ARS-USDA, Florence, SC
J. Johnson	Univ of Georgia, Experiment, GA
J. Lemunyon	SCS-USDA, Ft. Worth, TX
S. Oberle	ES/CES, Iowa State University, Ames, IA
M. Selim	Lousiana State Univ, Baton Rouge, LA
S. Smith	ARS-USDA, Durant, OK
F. Swader	OSEC-USDA, Washington, D.C.
W.C. White	Resource Washington, Inc., Washington, D.C.

¹ B. G. Ellis, Evaluation Panel representative

² J. Hook, Chair of Work Group

³ P. G. Hunt, Recorder

PRODUCTION MANAGEMENT SYSTEMS

A major threat to the quality of national water resources is non-point source pollution from agricultural croplands, pastures, and feedlots. Agricultural management activities affecting these resources can impact on the transport of pollutants from the land to surface and groundwater. The available information on results of management alternatives is sketchy, and usually qualitative. It is for this reason that imaginative research on components of systems, and their combination into simple or comprehensive management alternatives, is essential and must be encouraged.

Research funded under this general RPA of the Water Quality Program addresses the USDA Program objectives as follows.

USDA Research Plan for Water Quality 1989--Objectives 1, 3, 5, 6

USDA Water Quality Initiative 1992 Workplan--Objectives 1,2

State of Current Research

The working group was concerned with developing measures to reduce sources of potential pollutants in agriculture, cultural techniques to control pollutant concentration in surface and groundwater, and predictive models that facilitate management decisions on field, farm, and watershed scales. Results given here are from both new and ongoing research supported by funds from the water quality initiative. Noteworthy accomplishments can be grouped as follows.

Vegetation Filter Management

Trees reduce sediments and nitrate. Vegetation uptake and denitrification were both effective for nitrate removal in riparian zones. A 50m forest buffer reduced sediment concentration in surface runoff water to less than 10% of that leaving the cropped field. A restored forest buffer removed less nitrate during the first year than a mature forest. (GA) [TT-1, 2]

Grass filters effectively intercept pollutants. Studies of their impact on water quality have been completed using filter strips 15 to 30 ft wide. Trapping efficiencies for sediment, nitrate-N and atrazine ranged from 93% to 99.7% during runoff from a 2 hr rain at the rate of 2.5 in/hr. (KY) [TT-2, 3]

Vegetated filters intercept sediment and nitrate. Vegetation between agricultural fields and small streams is a very effective method for improving water quality by removing sediment and P from surface flows. Nitrate is removed from subsurface water by plant roots. Vegetation filters are cost effective for ensuring high water quality in streams. (NC, VA) [TT-3]

Predictive Techniques

Animal waste and plant nutrient components have been incorporated into the model Groundwater Loading Effects of Agricultural Management Systems (GLEAMS). It was also adapted for evaluating various management systems including forest management and application to risk assessment for pesticide registration decisions. The GLEAMS model was also successfully linked to a solute transport model to account for chemical transport below the plant root zone. Model maintenance and user support is provided. (GA) [TT-1]

EPIC and SWRRB models modified for technologists and farmers to use. A manure land disposal management component was added to the Erosion Productivity Impact Calculator (EPIC). EPIC and the Small Watershed Rainfall Runoff Budgeting (SWRRB) models were modified to meet SCS needs for water quality assessment. (TX) [TT-2]

Management Systems

These include predicting pesticide movement and degradation in soils, identifying efficient and cost effective pesticides for different crops, and improving large-area Geographical Information System (GIS) management aids to facilitate choosing environmentally sound practices.

Computer software to estimate pesticide leaching and degradation was developed and field tested by combining chemical parameters (partition coefficient and half-life), soil properties (organic carbon content, bulk density, field capacity and wilting point), weather and management decisions utilizing GIS and chemical transport models. The system is especially good for comparing fate of different chemicals, or a single chemical with different management systems. The aid is useful for decision-making at the farm level and for policy-making guidelines at watershed, county and state levels. (FL, OK) [TT-2]

Peanut pest control made easier and better. A knowledge-based computerized decision-support system can identify pesticides for controlling any pest for peanuts and ranks them for their impact on water quality. Parallel to that, the system calculates the cost of each practice. These two components will enable farmers to choose economically and environmentally sound practices. (FL, NC, OK) [TT-2]

Remotely sensed data on crop types, GIS, and improved models. Significant improvements have been made in methods of integrating remotely sensed site specific crop type data into a GIS and linking it to groundwater models on large area groundwater pollution potential, thus increasing its accuracy and allowing for the definition of fuzzy coverages useful for stochastic modeling. (NC) [TT-2]

Water Table Management

Shallow water table management can reduce pollution in surface water runoff and increase crop yields. However, additional work is needed to determine the range of water table levels that provide the most efficient crop response, pollution reduction potential, and farmer acceptance. (LA) [TT-2]

Research Needs and Opportunities

Research needs were developed under two categories: Management systems, and technology transfer. Expected results from proposed research will have an important impact in reducing the transport of pollutants in surface and groundwaters, both within and from agricultural ecosystems. The reduction will be achieved through development of new and innovative production management systems, and adoption of already developed and proven technology.

Management Systems

Predicting the effects of various management practices on water quality on a watershed scale will require development of different techniques from those that are effective at field and farm scales. This means a better understanding is needed of all processes contributing to chemical movement and degradation in watershed-scale systems.

Expected results. *Simple techniques for selection* among management practices based on water quality considerations, providing criteria for identification of these best practices.

Ability to predict changes in and by vegetated filters under a broad variety of conditions through better understanding of processes controlling removal of pollutants.

Better methods for handling animal wastes and utilizing them in farming systems without increasing contamination of water.

Refined tillage systems that minimize contaminants in surface and subsurface flow.

Management of whole farm units in a holistic approach including the economics of practice combinations, and minimizing effects of potential pollutants through refinement of soil, crop, water, and nutrient management systems, and improved machinery.

Quantification of risk for contaminants and associated practices to facilitate decisions and technology transfer.

Understanding the value of wetland riparian areas when integrated into farm- and watershed-scale units. [Note: Generally, research on chemical and biological processes of non agricultural wetlands is eligible for funding in the Natural Resources area of the National Research Initiative in CSRS.]

Technology Transfer

Several stumbling blocks remain for effective TT of information for environmentally sound management practices. These vary from the lack of appropriate techniques to ineffective availability or organization of information. Collaborative efforts of researchers, educators, and technologists in adaptive research and development can overcome these problems.

Expected results. *Prepare a compendium of relevant information* for technology transfer by ad hoc research and TT task forces so SCS and Extension workers can use it effectively.

Perfect and transfer easy-to-use models and/or GIS for region-wide problems of management for water quality, including how to organize, manage, and access large data bases. Software and associated techniques, such as digitized soil maps, and easy, rapid, and accurate ways to integrate selected data, must be tested and available for decision making.

Document the technology in computer models sufficiently well, with input by users, so the numerical process is understandable.

Program Management Recommendations

Identify areas for large, multi-disciplinary, multi-institutional projects for:

- Animal waste management systems
- Large watershed management models
- Riparian zone - wetland systems

Workshops of project leaders should be continued to facilitate technology transfer to user group.

Abstracts of research progress should be made available to all project leaders. [Note: The reports have been available and will continue to be.]

Enhance communication and exchange of information among scientists and specialists engaged in research and technology transfer relevant to water quality research funded by many sources, including: Awards from funds under the President's Water Quality Initiative; the NRI; the Sustainable Agriculture Research and Extension Program (SAREP); other federal and state sources; and base funding for federal and state research programs. This would be facilitated by operationalizing a water quality regional committee for the Southern Region.

Work Group Participants

<u>Name</u>	<u>Institution</u>
Billy Barfield	University of Kentucky, Lexington, KY
Cade Carter	ARS-USDA, Baton Rouge, LA
Wendell Gilliam ¹	North Carolina State Univ, Raleigh, NC
Rattan Lal ²	Ohio State University, Columbus, OH
Ralph Leonard	ARS-USDA, Tifton, GA
Birl Lowery	University of Wisconsin, Madison, WI
Richard Lowrance	ARS-USDA, Tifton, GA
E. Jane Luzar	Louisiana State Univ, Baton Rouge, LA
D. L. Nofziger	Oklahoma State Univ, Stillwater, OK
Ron Marlow	SCS-USDA, Washington, DC
Casson Stallings	North Carolina State Univ, Raleigh, NC
Kenneth L. Wells	University of Kentucky, Lexington, KY
J. R. Williams ³	ARS-USDA, Temple, TX

¹Wendell Gilliam, Recorder for work group

²Rattan Lal, Evaluation Panel member

³J. R. Williams, Chair of working group

SOCIAL SCIENCES

The objectives of this program point to the need of determining the economic effects of row crop or livestock production systems, evaluating the socioeconomic impacts of changes, and developing programs to speed the diffusion of recommended programs.

State of Current Research

Two projects with social scientists as principal investigators and an additional 2 as collaborators have been funded in the South under the current water quality initiative; whereas, nationally the total number is not large being 11 and 7, respectively. The current social science research is not adequate to provide the information needed for farm, state or national level decisions. Despite this limitation, the current research has achieved several accomplishments that we highlight:

Integration of GIS into socio-economic analysis of water quality issues has proven successful and offers a unique perspective on the social and private water quality improvement decision process. (AR, LA) [TT-1]

Tradeoffs between regional farm incomes and nitrate contamination associated with land applications of poultry litter were examined using a regional linear programming model linked with a GIS for a small watershed in Northwest Arkansas. Preliminary results showed if litter applications were restricted to an average of 200 lb N-equivalent per acre, incomes were projected to decrease by 5 to 6%. However, restrictions on applications to an average 100 lb N-equivalent per acre could reduce regional farm income related to forage by almost 40%. Work is underway to link the economic model and the GIS to a soil transport simulation model to examine relations between income and nitrate leaching losses from the potential plant rooting depth. (AR) [TT-1,2]

A successful integration of physical and natural science research with economic analysis was accomplished through interdisciplinary research. (FL, NC, OK) [TT-1, 2]

Research Needs and Opportunities

There is a wide range of social science issues that are of prime importance in the accomplishment of objectives in this water quality research initiative. The following research needs were considered especially prominent:

Understanding the macro level socioeconomic implications of regulations. In recent years, regulatory actions have been increasingly employed to deal with ground and surface water quality problems. Research is needed to understand the macro level socioeconomic implications of these actions for local communities, regional economies, and farm structures. Measurement of these effects through input/output analysis, regional econometric models, mathematical programming, sociological analysis, or other modeling techniques is necessary components for a policy analysis. Both market and non-market effects must be included.

Expected result. An understanding of the socioeconomic consequences of various regulations and policy options will facilitate more informed decision making.

Quantitative evaluation of impacts of strategies on agricultural income. Proposed strategies that will reduce the contamination of ground and surface water must be evaluated quantitatively to aggregate impacts on agricultural income to at least the watershed level. The distribution of effects should be documented.

Expected result. Producers are unlikely to utilize strategies that negatively affect farm income. Thus, research on the long-term and short-term implications of various strategies for farm income is essential.

Costs and benefits of enhancing water quality. Potential losses in agricultural incomes, and other costs of environmental action, should be compared relative to the benefits of enhanced water quality. Examples include the general public's willingness to pay for improved water quality, the potential savings in water treatment costs, and the possibility of health related benefits of improved water quality.

Expected result. If the benefits to the general public are extensive, they may be willing to support actions that would offset the costs to farmers of implementing programs to improve water quality.

Extent, effects, and needs in adopting practices. In many cases, technology to reduce water quality problems is available, but not fully utilized. Adoption and diffusion research is badly needed to determine the practices being used by producers, the extent to which best management practices are utilized, and the necessary steps to speed adoption of practices that will improve water quality. Important parts of this research are economic and sociological analyses

Expected result. We need to determine if adjustments by farmers can be brought about on a strictly voluntary basis. Or, if incentives and regulations must be employed, what structure and magnitude of incentives would be necessary?

Policy approaches for implementing practices and social benefits. Social science research is needed to address appropriate policy approaches to implement water quality directives. These include net social benefits of regulatory versus voluntary incentive-based approaches that need to be estimated for specific water quality goals. The distribution of effects should be documented as well.

Expected result. Such research will allow informed decisions about which types of policies will be needed to achieve various water quality goals.

Integrate social sciences into all phases of water quality research. It is critical that social science research build upon the successes of scientists in physical and natural sciences.

Expected result. Social science research can enhance the application of decision aid tools in determining the applicability, viability, and acceptability of management teaching techniques. Specifically, financial, economic, and social implications should be incorporated into many of the tools being developed to promote enhancing water quality.

Risk impacts on decisions and policy actions. Social scientists can further contribute to water quality research by considering how risk impacts producer decisions and policy actions, and how to incorporate stochastic elements into a decision analysis process.

Expected result. This would facilitate incorporation of risk factors into management decisions. The degree of risk associated with decisions that farmers must make is critical.

Program Management Recommendations

Retain reward points for proposals that include interdisciplinary research. It is strongly recommended that actions be taken to encourage more interdisciplinary research proposals that include social scientists along with the natural and physical scientists. Such proposals would be especially helpful in meeting the objectives of the water quality research initiative. They could concomitantly explore approaches to reduce the contamination of ground and surface water resources while considering the economic and socioeconomic consequences of such approaches.

Evaluation criteria for research proposals should be adjusted to specifically reward proposals that produce the socio-economic information needed to address the three principles of the water quality initiative.

Plans should be designed and implemented to broaden the base of interested and qualified social scientists. Efforts should be made to assure that the following groups are a part of the request for proposals (RFP) process. All of these are needed to accomplish the water quality program objectives.

Traditional agricultural economists. Farm management, production, and marketing specialists for the farm-level analyses.

Traditional policy analysts who deal with all aspects of federal agricultural and environmental policy.

Resource and environmental economists who are doing excellent research in water quality on grants/contracts from EPA, Department of Interior, NOAA, and other government agencies. Few of these appear to have been drawn into the CSRS water quality research areas even though the issues are the same non-market benefits, externalities, and questions of willingness-to-pay and willingness-to-accept.

Rural sociologists and others who have been working in adoption and diffusion research, and traditional farm and rural community development.

This can be more assured by advertising the RFP in professional newsletters of Agricultural Economics and Rural Sociology. A precise statement of the perceived value of socioeconomic analysis in the RFP materials should further stimulate responses from these groups.

Work Group Participants

<u>Name</u>	<u>Institution</u>
D. E. Albrecht ¹	Texas A&M University, College Station, TX
M. J. Cochran ²	University of Arkansas, Fayetteville, AK
Steve Crutchfield	Econ Res Service, USDA, Washington, D.C.
E. J. Luzar	Louisiana State Univ, Baton Rouge, LA
P. E. Norris	Oklahoma State University, Stillwater, OK
C. M. Smith	Pennsylvania State Univ, Alexandria, VA
Others were in attendance	

¹D. E. Albrecht, Evaluation Panel member
²M. J. Cochran, Recorder for work group

EDUCATION AND TECHNOLOGY TRANSFER

Twenty scientists and specialists representing Agricultural Experiment Stations and Cooperative Extension Services of the Land Grant Universities from the southern states, ES, ARS, SCS, Office of The Secretary-USDA (OSEC), the Corn Belt MSEA Project, and Resource Washington, Inc., met to discuss and evaluate USDA sponsored research funded by the President's Water Quality Initiative in the Southern Region. We examined whether the research is addressing major problems and will produce results which are transferable to Education and Technology Transfer (E&TT) clientele involved in or affected by water quality concerns.

Those attending had participated in various of the five RPA Work Groups and included a report by one person from each of those groups designated to evaluate the technology transfer situation within each group. The following represents a summary consensus from a lively discussion of cross-disciplinary scientists and specialists.

State of Current Research

Research on target. There was general agreement that research being conducted was on target in terms of goals and objectives established by USDA for this specially funded research.

Improved systems. Some projects have already produced results which are now being used by farmers in reducing the potential for production systems to adversely affect ground and surface water quality. This is notable in the riparian zone research and in water table management.

Application of GIS systems to water quality issues has also been shown to hold much promise, particularly for technology transfer.

Decision-making aids. Several projects have produced computer models and decision-making aids which have already been incorporated into resource and farm planning by SCS.

Solute movement from the soil surface through the root zone has been shown by research to be largely by preferential (bypass) flow in contrast to a traditionally used concept of uniform or piston flow. This has much potential impact on the accuracy and predictability of flow and solute movement prediction models. Traditional flow concepts do not take into account that as much as 90% of water movement can take place in less than 15% of the soil volume due to preferential or by-pass flow, as has been shown to be the case in some field studies. The potential impact on the accuracy of predictions is great.

Research Needs and Opportunities

The following needs are arranged by RPA Work Groups. They are based on observations by participants in the E&TT Group who had attended earlier sessions of the other groups. They are consensus comments and recommendations.

Fate and Transport

Identify specific audiences expected to use the results, which would include state and federal agencies, industry, and growers.

Involve other state and federal agencies, industry, and growers early in the research development process. This should be an ad hoc involvement and would form the basis of rapid transfer of information as it is being developed.

Obtain interdisciplinary input from stream ecologists, limnologists, and lake managers early in the research process.

Technology transfer expectations and record of development and/or use should be part of the project proposal and project reports, respectively. Either a direct involvement of technology transfer specialists would be needed, or researchers would need training and encouragement as to how to properly do this.

Transformation & Remediation: Pesticides, other Organics, Microbes

Practical technologies for disposal/remediation of rinsate waters that are both environmentally sound and legally achievable should be perfected so such information can be delivered to farmers and other pesticide users.

Equipment and cost for ULV pesticide use. Pesticide technology in ULV application holds much promise for reducing pesticide loading to ground and surface water. An unresolved issue is the cost of the new equipment needed to achieve ULV application.

Innovative techniques for bio-remediation of pesticide wastes, spills and other contaminated areas hold great promise. However, there is a need to develop both naturally enhanced microbial degraders as well as genetically engineered microorganisms (GEM). Although GEM are not authorized for release into the environment, further research is warranted to provide cost effective remediation.

Nitrogen, other Nutrients, Waste, Metals

"State of current research" in this RPA is judged in light of the following categories of water quality problems identified as:

Health threat (or potential) of nitrate-N in shallow groundwater. Documentation of the "problem" is scant, but the problem appears to be with some shallow wells having nitrate-N levels of 10-20 mg/L, with atypical cases much higher. The problem is often closely associated with use of animal waste.

Environmental threat (or potential) of P in surface water that could contribute to eutrophication of both fresh water and estuarine water.

Research projects in this RPA have reasonably close orientation on these problems. Several of the projects address the problems head-on, others only obliquely. Examples of the former include the animal (poultry) waste projects and the wheat fertilization project. The eight projects for the Southern Region in this Work Group, to date, have a close bearing on the problems stated above.

Research with animal wastes is showing the "management" aspect of associated problems. Site selection for such operations often is without proper consideration of sufficient land for the resulting nutrient loadings. The projects addressing specific crops appear to directly address problems of nutrient loadings and losses. Specific development of certain information would contribute materially to improved results from current projects of this RPA as follows.

Data on the mass of N and P by principal source currently entering the agricultural system in the Southern Region. Notable weaknesses center on N and P in livestock and poultry operations and crop residues, especially legumes.

Threshold levels of soil P associated with (or resulting in) water quality problems.

Maximum loading rates of N and P from animal wastes for typical land areas in the Region that constitute "problem levels" for surface water.

Means to utilize animal waste or to transform it to minimize the nutrient-loading impact on soils and water.

N diagnostic methods for field use that are "quick", easy to use, and reliable for quantitative assessments of N status.

Develop management practices to maximize nutrient recovery by the crop to which nutrients are applied. Ancillary to this is the development of management techniques to utilize "catch" crops for "nitrate absorption", after harvesting the primary crop, when conditions during the growing seasons have favored large quantities of nitrate-N remaining in the soil at harvest time.

Develop from existing data an assessment of "release coefficients", with time, for N and P from animal wastes and crop residues. A regional bulletin, funded through the Water Quality Initiative, would be a valuable instrument for improved nutrient management in the Region.

Develop a "background" paper on soil P and how management of high soil P levels can preclude detriment of water quality.

Production Management Systems

More effort on development of GIS systems as a means of accessing and classifying large data bases to expedite technology transfer on a regional basis.

Well documented codes or detailed documentation on specific models to make it possible to interface them with other models and supportive data bases in order to expedite use of some component of a model in development of integrated software.

Improve communications among scientists working in water quality so that they have a better perspective of where their research area fits in the "big picture".

Develop a workshop on technology transfer and require all principal investigators to attend to enhance rapid flow of research results to those who need them.

Increased Emphasis Required

Describe preferential or bypass flow of water and solutes in a manner that such flow patterns can be modeled.

Expected result. Obtaining this knowledge will remove a major restriction to reliable and predictable technology transfer.

Develop a system of classifying soils relative to similar preferential flow characteristics.

Expected result. This will greatly enhance the potential to transfer technology, particularly in scaling up information from specific soil/plant/environmental ecosystems to watersheds or major land resource areas (MLRA) in the South.

Expand application of GIS systems.

Expected result. This would make it possible to interface large multi-disciplinary databases on a geographic scale appropriate for decision making regarding groundwater and surface water quality issues.

Develop environmentally sound animal manure management systems.

Expected result. This information will be critical in technology transfer needs especially where confined animal production systems are important.

Develop soil nitrate tests which have predictive value in major MLRAs of the South.

Expected result. This would greatly improve N recommendations for cropland application, resulting in reduced chances of polluting water with residual nitrate.

Expand economic and social impact studies of projected remediation technology for improved water quality.

Expected result. Adoption of proven practices would be facilitated, thus improving voluntary management of environmental quality.

Up-scale lab and small plot research to a watershed or MLRA size.

Expected result. It is believed that large-scale research such as is being done on corn and soybean production in the Corn Belt (MSEA) is very effective as a direct technology transfer mechanism.

Initiate research to determine how preferential flow characteristics of soils in major MLRAs of the South can be effectively modified.

Expected result. This would cause solute movement through the soil rooting zone to be more predictable and easier to manage.

Program Management Recommendations

Require that project proposals and research reports contain a prefacing statement of no more than two concise sentences stating why the research is needed and how the results will be used.

Compile a Southern Region research bulletin documenting what is known about nutrient release rates from animal and plant residues in different soil/environmental areas of the South. We recommend that CSRS and/or ARS take the lead in making this possible, so that a regional reference of "standardized" release coefficients is available in the near future. This information is critically needed for P release coefficients.

Expand interdisciplinary research associated with livestock/poultry production industries to enhance management/utilization of animal wastes.

Promptly initiate communications between the principal investigators and principal user groups, including fertilizer industry and crop consultants.

Emphasize field validation of current prediction models and assessment of uncertainty associated with their use, rather than development of new models. This should be done for major crop production systems on environmentally sensitive landscapes and hydrologic zones.

Work Group Participants

<u>Name</u>	<u>Institution</u>
Dale Bucks	ARS-USDA, National Prog Staff, Beltsville, MD
David Bosch	ARS-USDA, Tifton, GA
T. C. Daniel ¹	University of Arkansas, Fayetteville, AR
Albert Garcia	Texas A&M University, College Station, TX
B. L. Harris	Texas A&M University, College Station, TX
Art Hornsby ²	University of Florida, Gainesville, FL
Chuck Kennerley	Texas A&M University, College Station, TX
Jerry Lemunyon	SCS-USDA, Fort Worth, TX
Richard Lowrance	ARS-USDA, Tifton, GA
Ron Marlow	SCS-USDA, Washington, D.C.
Joe Massey	University of Arkansas, Fayetteville, AR
Tom Mueller	University of Tennessee, Knoxville, TN
Steve Oberle	CES/ES-USDA, Iowa State University, Ames, IA
Eric Osborn	Texas A&M University, College Station, TX
Ron Phillips	University of Kentucky, Lexington, KY
Don Scott	University of Arkansas, Fayetteville, AR
Wayne Skaggs	North Carolina State, Raleigh, NC
Casson Stallings	North Carolina State, Raleigh, NC
Fred Swader	OSEC-USDA, Washington, D.C.
K. L. Wells ³	University of Kentucky, Lexington, KY
W. C. White ⁴	Resource Washington, Inc., Washington, D.C.

¹T. C. Daniel, recorder

²Art Hornsby, recorder

³K. I. Wells, Evaluation Panel member

⁴W. C. White, recorder

APPENDIX

THE PRESIDENTS INITIATIVE on WATER QUALITY APPENDIX

Abstracts of Research Progress, 1992 Report

The following abstracts are based on current results of research funded in part by water quality initiative awards by ARS and CSRS. The additional projects have inspired very useful research for improved management of potential pollutants from agriculture.

ARIZONA FARMSTEAD CONTAMINATION OF GROUNDWATER. H. Bouwer, A. J. Clemmens, USDA-ARS, Phoenix, AZ; T. Maddock, University of Arizona. Report Period: 8/91 - 2/92.

Model studies are carried out to determine if contamination of groundwater is due to point or non-point sources. With a point source, contaminant concentrations in well water should decrease with continuous pumping. For non-point sources, they should stay about the same. "Disappearance" curves are being developed to estimate the extent of the point-source contamination and to develop the best strategy for remediation. For non-point source contamination, deepening of wells may improve well water quality but the contaminant eventually may show up again. Model studies are performed to see how long this may take.

ARIZONA NITROGEN FERTILIZER AND WATER TRANSPORT UNDER 100% IRRIGATION EFFICIENCY. H. Bouwer, F. J. Adamsen, D. J. Hunsaker, R. C. Rice, and F. S. Nakayama, USDA-ARS, Phoenix, AZ. Report Period: 2/91 - 2/92.

Cotton was grown using level basin flood irrigation in 1991, and wheat planted in the winter of 1992. Chemical tracers were applied with each irrigation. Current standard practices, and surface application of fertilizer based on soil test levels, petiole nitrate-N feedback, and leaf chlorophyll content, and fertilizer application in the irrigation water were evaluated in combination with 100% and 80% irrigation efficiency. One of the chemical tracers, m-trifluorobenzoic, caused the cotton leaves to curl and bolls to abort. The plants eventually overcame this effect but yields were reduced in the affected plots. A greenhouse study was initiated to determine whether the tracer or some impurity in the materials used caused the damage to the cotton. Preliminary results from the greenhouse study showed no damage to seedlings when grown in potting mixture. Evaluation of the tracers in field soil has been started.

ARIZONA NONIDEAL TRANSPORT OF PESTICIDES IN SOILS. M. L. Brusseau, University of Arizona. Report Period: 9/1/91 - 2/1/92.

The past five months, which represent the beginning of this grant, have been used primarily to set up and test the miscible displacement systems that are to be used to accomplish the stated objectives. Two systems are operative, one for transport experiments performed under water-unsaturated conditions and the other for saturated conditions. The results of preliminary experiments demonstrate that the systems are operating effectively and that they will successfully provide sorption and transport data. In addition, they have also been shown useful for investigating coupled processes, in this case the effect of simultaneous sorption and biodegradation on transport. Another activity performed over the initial period of the project was an evaluation of the usefulness of quantitative structure activity relationship (QSAR) analysis for investigating the mechanistic aspects of sorption. Based on the results, the polymer analogue is suggested as the phenomenological model of choice for investigating and evaluating sorption mechanisms for soil systems.

ARIZONA DEVELOPMENT OF A PROTOTYPE DECISION SUPPORT SYSTEM FOR WATER QUALITY MODELS. L. J. Lane, D. S. Yakowitz, USDA-ARS; J. J. Stone, P. Heilman, B. Imam, University of Arizona. Report Period: 4/90 - 2/92.

A prototype Decision Support System to evaluate and rank alternative management practices on farmland with respect to surface and groundwater quality has been developed and is currently being implemented. The simulation model has been configured and coded with the following components: hydrology, erosion/sediment, pesticide (from GLEAMS), nutrient (from CREAMS), crop growth (from EPIC) and economics (from CARE). The multi objective decision model has

been implemented and combines graphical scoring functions and a new ranking method that removes much of the subjectivity that dominates other methods. The user-interface and data bases are currently under development. Model verification and validation is in progress.

ARIZONA MOLECULAR METHODS FOR EVALUATION OF MICROBIAL QUALITY OF GROUNDWATER. I. L. Pepper, C. P. Gerba, S. D. Pillai, University of Arizona. Report Period: 7/1/90 - 2/20/92. Primers from the lamB gene allow amplification of DNA from fecal coliform indicator organisms via polymerase chain reaction (PCR). Primers from the phoP gene and Hin and H-li genes allow specific detection of Salmonella spp. The lamB primers were used for analysis of indicator organisms in distilled water. Detection was by Et Br or gene probe. Water samples were processed through a Sterivex filter unit, and concentrated by either membrane filtration, or cell pelleting with the latter method giving increased levels of coliform detection. Sensitivity decreased in groundwater samples, and was dependent on water quality. The lowest number of cells detected was 10⁴ CFU's per 2 liters.

ARIZONA MANAGEMENT PRACTICES AND PREFERENTIAL FLOW TRANSPORT OF AGRICULTURAL CHEMICALS. A. W. Warrick, John E. Watson, Jon P. Chernicky, David O. Lomen, University of Arizona. Report Period: 6/89 - 12/91.

A non-adsorbed tracer (bromide), a soil adsorbed tracer (FD&C Blue No. 1 Dye) and a moderately adsorbed herbicide (Prometryn) were applied to field plots by injection into a pressurized water delivery system. The impact of initial soil moisture conditions on preferential flow transport was investigated by including plots that had not received irrigation water for a substantial length of time and plots that were subject to a 10 cm irrigation water application immediately prior to the tracer and herbicide applications. A backhoe was used to excavate trenches in each plot. Soil samples were collected in a grid configuration immediately adjacent to each other from each trench. Samples were extracted to determine concentrations of bromide, dye and herbicide. Profiles of concentrations with depth have been compared to modeled data using a convection-diffusion solution and best-fitted to estimate retardation and dispersion coefficients. Results were generally reasonable for bromide, but more erratic for the prometryn.

ARIZONA THE PERSISTENCE OF PREFERENTIAL FLOW DURING AN INFILTRATION EVENT. A. W. Warrick, John E. Watson, Janick Artiola, Jon P. Chernicky, Univ of AZ. Rpt Per: 7/91 - 2/92.

A field research plot has been set up at the Maricopa Agricultural Center. Placement of the sampling devices was completed in February 1992. The treatments are soil condition at the time of herbicide and tracer application. Included are a. Non-cropped, surface-tilled and b. cropped-enhanced macropore development. Tracers will be used to differentiate between portions of the irrigation water so that the pulse containing the herbicides can be distinguished from the herbicide free pulse. Conservative tracers to be used include bromide as KBr and three fluorinated benzoic acids. Solution sampling equipment installed include gravity-fed, hollow glass blocks (pan lysimeters) and suction lysimeters.

ARKANSAS & TEXAS MODELING WATER QUALITY IMPACTS OF SURFACE-APPLIED BROILER LITTER TO IDENTIFY BMPs. T. C. Daniel, D. R. Edwards, University of Arkansas, and R. H. Griggs, Texas A&M University. Report Period: 7/90 - 3/92.

Runoff data are being evaluated from three rainfall simulation runs conducted at two intensities on three wastes. Solute movement through the vadose zone is being monitored continuously with suction cup and pan lysimeters under constant vacuum. Concentrations of nutrients in the runoff were higher than literature values, especially dissolved phosphorus. Nitrate concentration of the soil water is directly related to application rate. BMPs should focus on timing of manure application and limiting dissolved phosphorus in the runoff. During the reporting period, eight manuscripts were submitted for publication and seven presentations conducted.

ARKANSAS OPTIMIZING ON-FARM DISPOSAL OF PESTICIDE RINSATES. T. L. Lavy, J. D. Mattice, D. C. Wolf, R. E. Talbert, University of Arkansas. Report Period: 9/89 - 2/92.

An activated charcoal filtration unit has been designed which effectively removed the pesticides atrazine, benomyl, carbaryl, fluometuron, metolachlor, and trifluralin from pesticide-laden wastewater. The system is simple in design and use. Several common dyes have been studied which could be used as visual assays to determine the remaining adsorptive capacity of charcoal used in an activated charcoal filtration system. Studies assessing the biodegradability of charcoal-bound pesticides suggest that the age of spent charcoal will play an important role in controlling the bioavailability of sorbed pesticides. Options to incinerating spent charcoal are being investigated.

ARKANSAS DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM TO ANALYZE NITRATE CONTAMINATION FROM THE LAND APPLICATION OF POULTRY LITTER. H. D. Scott, M. J. Cochran and W. F. Limp. University of Arkansas. Report Period: 9/89 - 2/92.

A geographical information system has been developed for the Muddy Fork watershed in northwestern Arkansas. Primary and secondary databases along with site data were developed for the watershed. Statistical correlations and regressions were used to relate landscape features to the nitrate-N concentrations in wells and springs. Soil drainage classification and distance from a poultry house were the statistically significant landscape parameters. A deterministic computer model has been developed to describe the fate of N after the application of poultry litter to pasture. The model predictions compared well with the results obtained in a 2-year field study. An economic model was also developed for the watershed based on three scenarios. The environmental and economic scenarios indicated that profits were 64% and 95% of the baseline scenario, respectively.

CALIFORNIA WATER QUALITY MANAGEMENT ON THE WESTSIDE SAN JOAQUIN VALLEY. J. E. Ayars, C. J. Phene, H. I. Nightingale, G. S. Banuelos, USDA-ARS, Fresno, CA. Report Period: 12/90-2/92.

The demonstration sites were selected and installation of subsurface drip systems on two 30 acre sites was completed in the spring of 1991. Processing tomatoes and cotton were grown during 1991. In addition to the drip system, surface irrigation using automated lay-flat tubing and gated aluminum pipe were used. Tomato yields were about 19% higher in the drip plots than in the furrow irrigated plots with about 10% less water being used in the drip plots. Cotton yields were comparable in both the drip and furrow irrigated plots. A field day co-sponsored by the California DWR and Westlands Water District was held at the site to display and discuss subsurface drip technology to a group of 50 people.

CALIFORNIA DISSOLVED ORGANIC MATTER IN SOIL AND NATURAL SYSTEMS AND ITS ROLE IN GROUNDWATER POLLUTION. A. C. Chang, Z. R. Hinedi, and R. W. K. Lee, University of California, Riverside. Report Period: 7/90 - 2/92.

A set of 33 water samples was obtained from wells located in the Chino-Corona dairy area. The $\text{NO}_3\text{-N}$ and chloride concentration in the water samples ranged from 3.27-113 and 4.00-230 mg L⁻¹, respectively. Each sample was double filtered then freeze dried. The residue was suspended in heavy water (D_2O) then analyzed by ^1H Nuclear Magnetic Resonance. The spectra obtained were highly resolved often showing multiple coupling. A two-dimensional ^1H - ^1H NMR experiment was run on one sample to detect coupled spins. The $\text{NO}_3\text{-N}$ contaminated groundwater exhibited a distinctively different dissolved organic matter (DOM) matrix than the background water. The spectra will be analyzed using a pattern recognition algorithm. In a laboratory study we examined the association of DOM with $\text{C}_6\text{H}_5\text{F}$. Pulsed Field Gradient Spin Echo NMR was used to determine the self diffusion (D) coefficients of $\text{C}_6\text{H}_5\text{F}$, DOM molecular species, and $\text{C}_6\text{H}_5\text{F}$ -DOM. Based on their D values, at least two $\text{C}_6\text{H}_5\text{F}$ -DOM complexes could be distinguished from the free $\text{C}_6\text{H}_5\text{F}$.

CALIFORNIA ASSESSMENT OF SOIL SALINITY AND SALT-LOADING TO GROUNDWATER. D. L. Corwin, J. D. Rhoades, S. Lesch, P. J. Vaughan. Report Period: 1/91 - 2/92.

An integrated approach to estimating soil salinity profiles and solute loading to the groundwater was developed and implemented in a study area comprising 6000 acres in the central valley of California. Soil salinity associated with both mobile and immobile water phases has been measured

throughout the area using both a four-electrode resistivity technique and an electromagnetic induction instrument. 1184 soil samples were taken in the area and were analyzed for saturation percentage and EC_e . Detailed chemical analyses of pH_e , HCO_3 , Cl , SO_4 , NO_3 , Na , K , Ca , Mg , SAR and B were performed for 280 soil samples. These data, along with irrigation history and other kinds of data will be used as input to the TETrans solute transport model which calculates solute redistribution in the vadose zone and solute loading to the groundwater. Updated versions of the TETrans solute transport package were developed for both Macintosh and IBM-compatible computers. Over 250 copies have been distributed to users. A GIS database incorporating TETrans is under development for the study area. Assistance is being provided to four agencies who wish to use the mobile salinity assessment technology in their water quality protection programs.

CALIFORNIA A WATER DESELENIFICATION PROCESS USING ACCELERATED MICROBIAL VOLATILIZATION. W. T. Frankenberger, Jr., Univ of CA, Riverside. Report Period: 6/90 - 4/91. High levels of selenium in agricultural drainage water has promoted the need for immediate remediation of such waters. Studies are being implemented to utilize indigenous microorganisms existing in such waters. Optimization of both biological and environmental factors are key components in successfully combating this problem. We have successfully isolated bacterial isolates from such waters that have the ability to volatilize selenium and significantly reduce the selenium inventory. Acceleration of such a methylation process has been brought about by the use of well-aerated, well-mixed protein/cofactor-amended water. The scope of this project is to ultimately understand the biological process of selenium volatilization principally with respect to the genetics and the enzymological framework. It is the goal of this group to eventually provide a cost-effective system for the removal of selenium-contaminated water.

CALIFORNIA COMPARISON OF TRANSFER FUNCTION AND MECHANISTIC FLOW AND TRANSPORT MODELS. W. A. Jury, Z. J. Kabala, S. R. Yates, Univ of CA, Riverside. Rpt Period: 7/91 - 2/92. A two dimensional numerical water and chemical transport model was adapted to the set of problems covered under this project by generating a random grid of hydrologic and solute transport and retention functions to represent a heterogeneous unsaturated field. This random field was endowed with properties similar to those measured in real experiments. Using a supercomputer, we solved for water content and solute concentration values for the case of uniform water application to the soil surface. The output at a given depth below the surface is being averaged to represent various field sampling devices. Now that the numerical code has been developed, we are proceeding with the set of problems covered under our proposal, simulating conventional analysis of the transport problem and comparing it to predictions made using a transfer function model.

CALIFORNIA FIELD TEST OF A STOCHASTIC, ORGANIC SOLUTE, TRANSPORT MODEL. D. Rolston, L. Kavvas, J. Biggar, K. Scow and B. Hammock, Univ of CA, Davis. Report Period: 7/90 - 3/92. New stochastic methodology has led to analytical expressions for the one-dimensional, time-space varying probability density function for solute concentration under a nonstationary flow field. Characterization of soil and hydraulic parameters for the field are completed, and mean and covariance behavior of water flow were characterized from two soil-water drainage cycles. Comparison of theoretical and empirical (Monte-Carlo) probability density functions showed good agreement. A nonreactive tracer (chloride) has been applied to 24 subplots and a second application made to 8 of these. Mass fluxes varied greatly between the two applications. The chloride data are currently being used for validation of the stochastic methodology. Time domain reflectometry (TDR) was evaluated as a rapid and inexpensive technology for measuring solute transport in soil. The movement of a chloride pulse through 45 cm of soil could effectively be monitored with TDR. Application of a reactive tracer (atrazine) is planned.

CALIFORNIA WATER QUALITY MODELS FOR IRRIGATED SALT-AFFECTED SOILS. M. Th. van Genuchten, J. D. Rhoades, S. R. Yates, D. L. Corwin, and W. F. Spencer, U. S. Salinity Laboratory, USDA-ARS, Riverside. Report Period: 5/90 - 2/92. The purpose of this project is to develop numerical models for predicting the movement of water and dissolved constituents in irrigated salt-affected lands, and to use these models to develop

scenario's for achieving agricultural sustainability and salt balance for affected areas. An improved one-dimensional model (HYDRUS) has been developed for variably-saturated flow and chemical transport in and below the soil root zone. The model includes hysteresis in the soil hydraulic properties and nonlinear solute exchange between the soil solution and the solid phase of the soil. Version 1.1 of a two-dimensional finite element code (SWMS_2D) has also been released. The two-dimensional code considers water and solute movement in nonhomogeneous unsaturated, partially saturated, or fully saturated media. Both codes are available upon request. Results of this study should help in formulating improved management strategies that minimize the leaching of salts and potentially toxic substances to underlying groundwater systems.

CALIFORNIA, RHODE ISLAND & WASHINGTON DC ECONOMIC INCENTIVES TO REDUCE AGRICULTURAL POLLUTION. J. E. Wilen, C. L. Kling, University of California, Davis, D. Wichelns, University of Rhode Island, M. Weinberg, USDA-ERS, Washington, D.C. (former graduate student, UC Davis). Report Period: 6/90 - 2/92.

Economic incentives to improve water management and reduce agricultural pollution of water resources have been implemented in the San Joaquin Valley. Farmers have responded to higher prices for irrigation water with improvements in existing irrigation practices. Drought-induced reductions in water supply have hastened investment in water-conserving irrigation technology. Dynamic analysis of farm-level investment decisions suggests that economic incentives may also be useful to increase the rate of investment in irrigation technology. Efficiency properties and fiscal effects of economic incentive programs are examined in a regional simulation model. Additional district-level and regional incentive programs will be analyzed in 1992.

COLORADO ROOT ZONE WATER AND CHEMICAL TRANSPORT AS ALTERED BY FLOW PATHS, CROP ROOTING, AND MANAGEMENT. L. R. Ahuja, J. G. Benjamin, USDA-ARS, Fort Collins. Report Period: 4/91 - 2/92.

A pilot study of chemical leaching in crop row versus interrow areas started earlier was completed. There were two major findings: (1) In corn on a sandy loam soil, there was significantly less leaching of a surface-applied tracer chemical beneath crop rows than beneath interrows; and (2) overall leaching was less under soybean than under corn. A modeling study of macropores in a silty clay loam soil showed: (1) Appreciable fast-flow through macropore, occurred only at high rainfalls; (2) relatively greater amount of water flowed through macropores than that of chemicals; (3) more of a pesticide was transported than nitrate; and (4) soil evaporation increased the amount of chemicals entering the macropores. Macropores not open in the soil surface conducted very little of water or chemicals.

COLORADO EFFECT OF BEST MANAGEMENT PRACTICES ON GROUNDWATER QUALITY. D. S. Durnford, J. C. Loftis, L. R. Walker, Colorado State University. Report Period: 6/91 - 2/92.

The objectives of this study are to determine to what extent BMPs can reduce groundwater contamination and provide a method for predicting the effects of management practices on groundwater quality. Two study sites were chosen in the San Luis Valley that were adjacent but applied chemicals differently. The sites were characterized and both the shallow groundwater and the soil zone were monitored for nitrates and pesticides. From the preliminary analysis, it appears that the spatial variability of both the soil physical parameters and the chemical application rates is high. In addition, the preliminary data show some indications that the chemicals may move to the groundwater through preferential pathways. We will explore these possibilities in the next phase.

COLORADO WATER AND NITROGEN MANAGEMENT TO PROTECT GROUND-WATER QUALITY. R. F. Follett, M. J. Shaffer, L. K. Porter, A. R. Mosier, all USDA-ARS. Report Period: 1/90 - 2/92.

Nitrification Inhibitor: An inexpensive nitrification inhibitor was developed in Ft. Collins, a Patent Application accepted by ARS, extensive field tests conducted, the IFDC is investigating possible manufacturing processes. User Friendly N-Management Principles: Two books, a computer model, and a data base for the Midwest are published and Technology Transfer is being implemented. NLEAP-GIS Technology: Techniques have been developed to link the NLEAP computer model to GIS using the Sycamore Creek Watershed in MI for testing. Analyses indicate that nitrate

leaching "hot spots" occur within a watershed rather than across the entire landscape. The important fact for nitrate leached is the amount of residual nitrate in the soil profile. Irrigated Corn/Labeled Nitrogen Research: A depleted ^{15}N field study to determine effects of irrigation levels, fertilizer N-rates show a considerable time lag for transport of surface applied N through a 1.22m soil profile.

COLORADO WATER AND NITROGEN MANAGEMENT TO PROTECT GROUND WATER QUALITY. D. F. Heermann, R. F. Follett, M. Shaffer, H. R. Duke, E. E. Schweizer, USDA-ARS, Ft. Collins, CO. Report Period: 2/91 - 2/92.

An NLEAP-GIS application is in progress to identify nitrate-N leaching hot-spots and suggest management strategy alternatives across the Northern Colorado Water Conservancy District. A cooperative study with the NCWCD is providing soil land use, crop management, ground water and nitrate-N data suitable for model validation. The NLEAP model is identifying nitrate-N leaching problem areas. Nitrification inhibitors were used in irrigated corn and wheat field experiments. In corn, the nitrification inhibitors tested permitted only a small accumulation of nitrate in the root zone compared to that of the check treatment; a second year of wheat data is being collected. A literature search was completed for developing weed/crop models for managing weeds in barley and pinto beans. Data on the height and number of weed species in 15 corn fields were collected at harvest to estimate seed production and changes in weed seedbanks. Preliminary design of an irrigation system for chemigation studies and a review of the current chemigation technology was completed. Tifton, GA was visited to learn the details of their chemigation studies and the needs for future development.

COLORADO & UTAH CROP MANAGEMENT KNOWLEDGE BASED SYSTEM FOR REDUCING GROUNDWATER CONTAMINATION. J. Loftis, I. Broner, P. Soltanpour, K. Thompson, Colorado State University, and R. Peralta, R. H. Hanks, Utah State University. Report Period: 6/90 - 2/92.

A system is being developed for irrigated corn that will produce fertilizer recommendations and schedule irrigation to maintain yield while minimizing the potential for groundwater pollution by nitrates. A fertilizer module has been developed which uses BMPs, heuristic knowledge of soil fertility, and crop requirements to produce recommendations. An expert system shell has been embedded within the module to serve as an inference engine. An irrigation module will be developed, and both modules will be linked to a nitrate leaching model to minimize contamination potential. The USDA-ARS's NLEAP model will be incorporated to perform the nitrate leaching analysis.

COLORADO PREDICTING PESTICIDE LEACHING FROM SPATIAL VARIABILITY OF TRANSPORT PROPERTIES. J. C. Loftis, D. B. McWhorter, G. Butters, D. S. Durnford, Colorado State University, and H. R. Duke, R. F. Smith, USDA-ARS, Fort Collins, CO. Report Period: 6/90 - 2/92.

Three field studies of spatial variability of soil properties related to solute transport have been completed. The smallest-scale study (5m by 5m) dealt with transport of an adsorbed solute, atrazine under flood irrigation. Laboratory results are not yet complete. A larger-scale study (20m by 20m) evaluated spatial variability of soil moisture content and of median solute velocity using a bromide tracer under sprinkler irrigation. The largest-scale study (120m by 120m) considered steady-state infiltration rate as the variable of interest. Results of the third study have not yet been analyzed. However, geostatistical analysis of the measured variables in the second study indicate that the appropriate forms of statistical models to describe spatial variability are dependent on the spatial scale of interest. The remainder of the study will investigate the consequences of statistical model selection on statistical design of soil sampling programs for estimating means, percentiles, or proportions of random variables related to solute transport.

CONNECTICUT PREFERENTIAL FLOW OF ATRAZINE IN BANDED AND BROADCAST TREATMENTS IN CORN. K. Guillard, G. S. Warner, K. Hatfield, J. Stake, Univ of CT. Report Period: 6/91 - 2/92.

Installation of zero-tension pan lysimeters into a field to be planted to corn was completed during the growing season of 1991. A total of 48 lysimeters were installed. Thirty-two lysimeters (two under row areas, two under interrow areas; four replicates) were installed beneath undisturbed soil profiles in plots to receive either banded or broadcast applications of atrazine. In addition,

sixteen lysimeters (one under a row area, one under an interrow area; four replicates) were installed beneath disturbed soil profiles in each treatment. Lysimeter installation was completed too late in the growing season to seed corn and apply atrazine treatments. Water volumes are being obtained from each lysimeter after sufficient rainfall to assess the success of not functioning properly before treatment application in 1992. Preliminary soil cores have been taken from the field and procedures for the laboratory studies are being developed.

CONNECTICUT DEGRADATION OF PESTICIDE WASTES AND CONTAMINATED MEDIA. J. J. Pignatello. Report Period: 7/90 - 1/92.

A number of pesticides were treated with ferrous or ferric salts and hydrogen peroxide ($\text{Fe}/\text{H}_2\text{O}_2$), or the same in combination with UV/visible or UV light above 300 nm ($\text{Fe}/\text{H}_2\text{O}_2/\text{h}\nu$). In weak acid (optimum pH 2.8), $\text{Fe}/\text{H}_2\text{O}_2/\text{h}\nu$ treatment of herbicides 2,4-D and 2,4,5-T resulted in their rapid and complete mineralization to harmless inorganic forms, HC1 and CO_2 , in less than 1 h. Only 5 moles peroxide per mole herbicide was required, indicating supplementary consumption of oxygen. Atrazine was dechlorinated but the atrazine ring remained intact. A number of Fe (III)-chelates were soluble and catalytically active in the dark at pH 6, giving 80% mineralization of 2,4-D and 2,4,5-T. Three chelates transformed atrazine, baygon, carbaryl, and picloram, but not trifluralin.

DELAWARE & MARYLAND NITRATE LEACHING FROM SOYBEANS AND SUBSEQUENT CONTAMINATION OF GROUNDWATER. J. J. Fuhrmann, B. L. Vasilas, University of Delaware, and J. S. Angle, University of Maryland. Report Period: 7/90 - 2/92.

Soybean and fescue control plots have been monitored in DE (loamy sand Coastal Plain soil) and MD (silt loam Piedmont soil) since Fall 1990. To date, there is no consistent evidence at either location of elevated nitrate levels in groundwater under soybeans as compared to the fescue controls. Soil samples collected at the MD location have shown higher concentrations of soil nitrate under soybeans than under fescue, but corresponding results for DE have been less consistent. Isotopic analysis of the DE soil taken from plant-free lysimeters amended with ^{15}N -labeled soybean residues indicated that mineralized N moved to the 90 to 120 cm depth within 6 months of harvest. In summary, despite instances of greater concentrations of soil nitrate under soybean than under fescue, there is as yet no consistent evidence that these nitrate levels are significantly impacting groundwater quality. However, the appearance of elevated ^{15}N -labeled nitrate concentrations at depths approaching the lower range of plant rooting suggests leaching may occur in the early Spring prior to significant plant root development.

DELAWARE LEACHING, SORPTION AND BIODEGRADATION OF HERBICIDES IN SUBSOILS OF A COASTAL PLAIN WATERSHED. J. T. Sims, J. J. Fuhrmann, and D. L. Sparks, University of Delaware, Newark. Report Period: 9/89 - 2/92.

Herbicide leaching and biodegradation experiments were conducted with soils from an Atlantic Coastal Plain watershed. Leaching of atrazine and metolachlor occurred more rapidly in a Klej loamy sand than in the Matawan sandy loam, likely due to the greater retention of these herbicides in subsoil horizons of the Matawan soil that were high in clay and Al/Fe oxides. The degradation potential of atrazine and metolachlor was studied with subsoil horizons from the Klej loamy sand, the Matawan sandy loam, and a Runclint loamy sand. Evolution of $^{14}\text{CO}_2$ was low ($< 1.6\%$), indicating that little mineralization of herbicides occurred in these subsoils. Methanol extracts from the soils receiving atrazine showed that between 89.5 and 91.6% of the extractable ^{14}C was present as the parent compound at the end of the experiment. Analysis of the methanol extracts of the metolachlor-treated soils indicated that 3 to 5% of the parent compound was subject to dechlorination. The results suggest that although certain coastal plain subsoils may have considerable potential to sorb herbicides, the mineralization potential of these compounds is low. Thus, herbicide that is leached to these subsoils may be sufficiently persistent to represent a long-term contamination threat to groundwater.

FLORIDA DEGRADATION OF TELONE II AND FENAMIPHOS IN SUBSOILS AND GROUNDWATER, AND BY MICROORGANISMS. L. -T. Ou, University of Florida. Report Period: 7/90 - 2/92.

Degradation rates of ¹⁴C-Telone in soil decreased with soil depth. Soil samples were collected from a Telone experimental site in Florida from surface to the top of watertables. Degradation rates of Telone in groundwater samples were low and were similar to the subsoil samples collected from the top of watertables. Fenamiphos in surface soil and shallow subsoil collected from a turfgrass site in Florida was rapidly degraded. This site has been treated with fenamiphos annually or biannually since early 1970. Half-lives for total toxic residue (fenamiphos + fenamiphos sulfoxide + fenamiphos sulfone) were very short, ranging from 0.9 to 4.2 days. Repeated applications of fenamiphos will not cause groundwater contamination.

GEORGIA CHEMIGATION IMPACTS ON WATER, SOIL, AND CROP QUALITY. J. E. Hook, J. G. Davis-Carter, and G. J. Gascho, University of Georgia and R. D. Wauchope, C. C. Dowler, A. W. Johnson, USDA-ARS, Tifton, GA. Report Period: 5/91 - 2/92.

A field comparison of chemigation versus conventional application of N and K fertilizer and atrazine, alachlor, and fenamiphos pesticides was monitored for nitrate and pesticides in soil water and shallow groundwater. Application of fertilizers through irrigation reduced nitrate leaching by spreading-out N applications. Less fertilizer was on the field at any time to be subject to leaching. Chemigation also allowed timely application of herbicides to the correct stage for weed control, when the soil was too wet for tractor traffic. Pesticides were found in soil water at 1.2 m within a few days after application by both methods. However, early results from this research suggest caution in recommending chemigation of pesticides which may move more readily in the freely draining fraction of soil water when preapplication soil water content is high.

GEORGIA WINTER COVER CROPS IN REDUCTION OF NO₃ LEACHING. J. W. Johnson, W. L. Hargrove, P. L. Raymer, University of Georgia, Tifton and J. E. Box, Jr. USDA-ARS, Watkinsville, GA. Report Period: 6/90 - 2/92.

The overall objectives of this research are to evaluate several winter annuals for rooting depth and residual N recovery and to compare winter cover crop and fallow for the amount of nitrate leaching over the winter months. We have two years of results from a preliminary evaluation of winter annuals for their adaptability as winter cover crops. These results show that canola, oats and forage turnips show promise as winter cover crops to prevent nitrate leaching. More detailed studies of rooting depth and N uptake for rye, canola, and crimson clover reveal that rye has the greatest amount of early growth and N uptake, but canola equals rye as the season progresses. Preliminary results from the tile drainage experiment indicate a rye cover crop significantly reduces the amount of water leaving the soil profile. Nitrate analyses are pending. The third year of the evaluation of the winter annuals and the second year of the extensive study of four selected winter annuals will be completed by June as planned. The third phase of the project on the influence of a cover crop on nitrate loss from tile drains has been initiated and will continue the next two years.

GEORGIA AGRICHEMICAL TRANSPORT AND CONTROLLING PROCESSES IN THE CLAIBORNE AQUIFER RECHARGE AREA OF SOUTHWEST GEORGIA. R. A. Leonard, D. D. Bosch, and C. C. Truman, USDA-ARS, Tifton, Georgia. Report Period: 2/91 - 2/92.

Atrazine, alachlor, and carbofuran pesticides applied in corn production on a Eustis soil near Plains, GA have been intensively studied since 1989 for their transport and transformation in the root zone, vadose zone and ground water. Studies also include chloride and bromide tracers and fertilizer nitrogen. Complete hydrologic, climatic, and cropping records have been maintained. Preliminary evaluation of models by the agencies involved (ARS, USGS, EPA) has been conducted. Little pesticide movement below about 3 m based on soil sampling has been observed. However, traces of pesticides and bromide appeared in ground water by the end of the second year. Studies on rates and pathways of atrazine degradation will continue to define the significance of hydroxyatrazine formation. Bromide data has shown a significant lateral transport vector in the vadose zone. A second plot area has been characterized by ground penetrating radar and future

studies will test this and other geophysical methods for non-destructive characterization of subsurface flow paths. Cooperative studies in other areas of the Claiborne Aquifer are being conducted with USGS to place the specific studies at Plains in regional perspective.

GEORGIA DEVELOP DECISION AIDS AND OTHER MODEL-BASED SYSTEMS FOR ENHANCING WATER QUALITY AND FARM PROFITABILITY. R. A. Leonard, D. D. Bosch, C. C. Truman, USDA-ARS, Tifton, Georgia. Report Period: 1/90-2/92.

In joint studies with D. B. Beasley, W. G. Knisel, and M. Smith of the University of Georgia, the GLEAMS model has been augmented to include a nitrogen and phosphorus component and animal waste as a nutrient source. Tillage, chemigation, crops, application methods, and other management-specific conditions were included as in the pesticides component. GLEAMS has been modified to improve the irrigation algorithms and options, adapt to forest conditions by changes in Leaf-Area Index and addition of canopy interception functions, and allow for in-inputs of saturated hydraulic conductivity values by genetic soil horizon. Model application studies were conducted to evaluate effects of variable pesticide half-life with soil depth, evaluate risk assessments for regulatory purpose using "worst-case" single event pesticide runoff vs long-term annual means, evaluate applicability in representing management options, and to evaluate soil-pesticide vulnerability groupings. GLEAMS was linked with a finite element model for transport in the vadose zone and preliminary evaluations were made with data from the interagency project near Plains, GA. Model maintenance and user support was provided for GLEAMS.

GEORGIA USE OF A RE-ESTABLISHED RIPARIAN FOREST TO CONTROL WATER POLLUTION FROM A MANURE APPLICATION SITE. R. Lowrance, R. K. Hubbard, USDA-ARS, Tifton, GA. Report Period: 2/91 - 2/92.

Field studies have been established at both a wetland restoration site below a center pivot used to apply liquid manure and a mature riparian forest which will be used to examine the effects of forest harvesting on water quality and soil processes. At the mature forest, sediment concentrations in surface runoff were reduced by over an order of magnitude (3800 mg/L to 331 mg/L) after flow through the 50 m buffer system. The first sampling to simultaneously measure denitrification, microbial biomass, and root biomass in the mature forest was completed in February. Nitrate levels in shallow ground water are elevated at the stream channel in the restored wetland indicating that it is not yet an effective nitrate sink.

HAWAII APPLICATION OF FRACTAL GEOMETRY FOR ESTIMATING SOIL HYDRAULIC PARAMETERS. H. Chang, G. Uehara, G. Y. Tsuji, University of Hawaii. Report Period: 7/90 - 2/92.

A method has been developed to estimate the water content-pressure and hydraulic conductivity-water content curves from particle size distribution. The particle size distribution is a fractal distribution and obeys the power law. The slope of the power-law in log-log plot is related to fractal dimension. The slope of the particle size distribution is in turn related to the slopes of the log-log plots of the water content-pressure and conductivity-water content curves. A computer software, called MESH (Method for Estimating Soil Hydraulic parameters), has been developed to enable users to compute and display water retention curves and conductivity-water content curves estimated from particle size data.

IDAHO MICROBIAL DETOXIFICATION OF PESTICIDE CONTAINERS AND RINSEATES. R. L. Crawford, D. L. Thill, H. W. Homan, University of Idaho. Report Period: 7/90 - 2/92.

A method using *immobilized microbial cells* for on-site detoxification of pesticide residues has been developed. A co-culture of the parathion degraders *Pseudomonas cepacia* and *Ps. dimunita*, entrapped in alginate and freeze-dried, had a survival rate (26 days, 20°C) of 10³-10⁵ cells/g beads. Immobilized and air-dried on kaolinite clay, the co-culture had a survival rate (33 days) of 10⁵-10⁷ cells/g. A *Ps.* sp. able to grow on 2,4-D was immobilized in alginate and freeze-dried, with good survival for 90 days. Optimal conditions for degradation of 2,4-D in Amine 4, Trimec, and Weedestroy by immobilized cells were 27-30°C and pH 7.3. Even after storage, both degraders degraded their target compounds in residues from used containers. Packets of freeze-dried microorganisms to treat rinseates and empty containers may eventually be produced,

eliminating hazardous residues at their source. This cheap, safe, and simple technology could greatly reduce pollution from the ≈ 30 active ingredients found in 90% of pesticides used in the U.S., and should be widely adopted by pesticide users.

IDAHO APPLICATION OF GENETICALLY ENGINEERED MICROORGANISMS IN REMEDIATION OF CHLOROAROMATICS. C. S. Orser and R. L. Crawford, University of Idaho. Report Period: 8/91 - 2/92.

Several critical steps have been attained for the completion of the first objective of this research, which is the construction of a recombinant *Flavobacterium* strain with enhanced metabolic activity against chlorinated aromatics. First, a reproducible procedure for the transformation of *Flavobacterium* sp. strain ATCC 39723 is being developed for demonstration of homologous genetic recombination. Second, the primary gene of interest for genetic modification, *pcpB*, which encodes pentachlorophenol (PCP) hydroxylase has been characterized to the nucleotide level. Third, the enzymatic reactions catalyzed by PCP hydroxylase and its surprisingly diverse substrate range have been described in detail.

ILLINOIS HERBICIDE DISSIPATION AND WEED CONTROL MODELS FOR REDUCING HERBICIDE CONTAMINATION OF GROUNDWATER. M. G. Huck, L. M. Wax, USDA-ARS, Urbana, IL. Report Period: 4/90 - 2/92.

Field studies of changes in soil water content and root growth profiles provided an experimental basis for estimating water flow and root water uptake patterns for predicting the rate and direction of solute movement within the profile. Root pruning by corn rootworm feeding, or xylem flow restriction by *phytophthora* infection of soybean roots restricted water uptake activity to surface soil. Nitrogen fertilization stimulated vegetative proliferation of roots, promoting utilization of water reserves held in the subsoil under drought conditions. A general 2-dimensional computer model for flow through porous media was adapted to the GLYCIM model for soybean growth and tested against experimental measurement data; predictions of water movement were generally accurate on dry-down, but sizeable predictive errors following heavy rainfall or irrigations were noted, since macropore flow is not considered by the model at present. A decision-support model for corn and soybean herbicide selection using soil characteristics from the SCS national soils database is ready for beta-test installation in selected county field offices.

ILLINOIS & OHIO WATER FLOW AND HERBICIDE TRANSPORT THROUGH SOIL MACROPORES. F. W. Simmons, C. W. Boast, Univ. of IL & E. L. McCoy, Ohio State Univ. Rpt Period: 8/90 - 3/92.

Herbicide movement through earthworm channels is a suggested mechanism for transport of soil applied herbicides through the root zone. Precipitation history shortly after herbicide application may be important in determining delivery of herbicides in macropore or soil matrix flow. We tested the hypothesis that a light rain may move herbicides into the soil matrix thereby allowing cleaner bypass flow in subsequent rainfall events. Undisturbed 7.5-cm diameter soil cores containing a single continuous macropore were sampled from a Drummer silty clay loam. Four saturation level groups between 0.25 and 0.85 were surface sprayed with alachlor, metolachlor, and atrazine. Of the herbicide entrained in the macropore, 6-17% was sorbed to the 7.5-cm long macropore wall. Rainfall amount and rainfall history following herbicide application will have a strong effect on herbicide entry into macropores. The sorption and hydraulic environment of the macropore system will determine ultimate delivery through the solum.

ILLINOIS & NORTH DAKOTA EVALUATION OF NATURAL ABUNDANCE ^{15}N TECHNIQUES FOR GROUNDWATER NITRATE STUDIES. R. M. Vanden Heuvel, R. L. Mulvaney, Univ. of Illinois; L. Prunty, B. R. Montgomery, North Dakota State University. Report Period: 5/89 - 3/92.

The lysimeter study comparing labeled ^{15}N fertilizer and natural abundance ^{15}N fertilizer to evaluate $\delta^{15}\text{N}$ techniques for assessing the origin of NO_3^- in groundwater had been completed. There was a wide range of background $\delta^{15}\text{N}$ values found in the unlabeled lysimeters (-2.5 to +27.0). Results from the labeled lysimeters indicated that isotopic dilution was extensive (at least 24 fold). This range of background $\delta^{15}\text{N}$ values and the extensive isotopic dilution would make it impossible to use natural abundance techniques even in simple systems. An adjacent field study (64 ha) also indicated $\delta^{15}\text{N}$ techniques could not separate sources of nitrate.

ILLINOIS WEED MANAGEMENT AND APPLICATION TECHNIQUES FOR GROUNDWATER QUALITY PROTECTION. L. M. Wax, E. W. Stoller, J. W. Hummel, D. M. Alm, and M. D. Cahn, USDA-ARS, and L. E. Bode, University of Illinois. Report Period: 4/90 - 2/92.

The research here employs both experimentation and simulation modeling to reduce herbicide input and increase application efficiency. A computer model of emergence proved successful in the field; and mechanistic water relations models were developed for three important weeds. Laboratory and field studies showed that starch encapsulated herbicides may reduce leaching with little loss of herbicidal activity. Field experiments using less than 50 g/ha of postemergence herbicides showed that weed competitiveness can be reduced and the weeds can serve as a 'cover crop' for corn and soybean production. A machine vision sensor has been tested that processes two images simultaneously to guide herbicide applicators through the field. A computer model that includes air turbulence has been developed to predict the spray deposition in a plant canopy.

INDIANA & GEORGIA DECISION SUPPORT SYSTEMS FOR EVALUATING GROUNDWATER QUALITY PROBLEMS. B. A. Engel, Purdue University, D. B. Beasley, University of Georgia, K. M. Embleton, J. P. Gurganus, X. Zhuang, L. Rhykerd, D. D. Jones, Purdue University, M. C. Smith, W. G. Knisel, University of Georgia, R. A. Leonard, USDA-ARS, Tifton, GA. Report Period: 6/90 - 2/92.

A decision support system is being developed to identify existing and potential groundwater pollution problems, to identify the source(s) of pollution, and to suggest corrective or preventative measures. A structure has been developed for constructing the system. Modules that will become part of the decision support system are being developed (9 in development) with 8 modules complete. These modules provide risk assessment and information concerning management practices to prevent groundwater quality problems. They are useful by themselves but will become even more useful when integrated within the decision support system. Laboratory and field data are being collected at the University of Georgia for module development and testing. The GLEAMS model has undergone additional testing and development at the University of Georgia and Purdue University. GLEAMS did a reasonable job in estimating masses of pesticides moved through the root zone and the timing of their appearance in tile flows for 5 years of field data from southeast Indiana.

INDIANA FIELD SCALE PREFERENTIAL FLOW ON STRUCTURED AND NON-STRUCTURED SILT LOAM SOILS. E. J. Klavivko, R. F. Turco, G. E. VanScoyoc, J. D. Eigel, Purdue Univ. Report Period: 9/91 - 2/92.

Data on tracer and pesticide losses in a subsurface tile drain provided additional evidence for preferential flow of agricultural chemicals at the field scale. Bromide and simazine were detected in the first drainflow events after application, with less than 1 cm net drainage from the soil. Using a simple piston-flow model as the comparison, these data indicate that at least 7% of applied chemicals may be moving through preferential flow paths. Total mass losses of simazine during the first 8 cm of drainage were roughly predictable from the bromide data, suggesting that in some cases, tracers may be useful for predicting pesticide losses even with preferential flow and non-equilibrium conditions. Initial mass balance calculations for bromide suggest that the tile drain methodology as proposed, may provide sufficiently good field estimates of preferential flow for many purposes.

INDIANA CONTROLLED RELEASE HERBICIDE FORMULATIONS - THEIR EFFICACY AND ROLE REDUCING GROUNDWATER CONTAMINATION. M. M. Schreiber and M. V. Hickman, West Lafayette, IN, both USDA-ARS. Report Period: 1/90 - 2/92.

Experimental starch encapsulated (SE) formulations of atrazine, alachlor and metolachlor were field tested for efficacy in 1990 and 1991 at 10 sites in the midwest representing a wide range of soils and weed populations. SE formulations controlled foxtails, pigweed, lambsquarter, common ragweed, kochia and smartweed as well as commercial formulations. Control of crabgrass, velvetleaf and cocklebur were more site specific and variable with excellent to poor control. Corn yields from plots treated with SE formulations were statistically equal or better than those from

plot treated with commercial formulations. Laboratory and field experiments indicate that SE encapsulated atrazine is significantly less mobile and less likely to move preferentially under conventional, chisel and no-till systems than commercial formulations.

IOWA AVAILABILITY OF ORGANIC CARBON FOR DENITRIFICATION OF NITRATE IN SUBSOILS AND GROUNDWATERS. J. M. Bremner and G. W. McCarty, Iowa State Univ. Rpt Period: 9/89 - 2/92. Work performed showed that the slow rate of denitrification in Iowa subsoils is not due to a lack of denitrifying microorganisms, but to a lack of organic carbon (C) that can be utilized by these microorganisms for reduction of nitrate. Studies concerning movement of organic C from surface soils to subsoils showed that drainage water from tile drains under agricultural research plots contained only trace amounts of organic C and had very little, if any, effect on denitrification of nitrate in subsoils. Other studies showed that aqueous extracts of surface soils promoted denitrification in subsoils and that their ability to do so increased with increase in their organic C content. Amendment of surface soils with corn or soybean residues led to a marked increase in the organic C contents of aqueous extracts of the soils and in the ability of these extracts to promote denitrification in subsoils, but growth of corn, soybean, wheat, and sorghum plants on surface soils did not have similar effects.

IOWA ANALYTICAL DETECTION OF CHEMICALS IN THE SOIL AND GROUND WATER. J. L. Hatfield, and R. L. Pfeiffer, USDA-ARS. Report Period: 3/90 - 2/92. Water and soil samples were analyzed for atrazine, alachlor, metribuzin, and metolachlor herbicides and nitrate-nitrogen from samples collected throughout the MSEA sites. The samples processed were over 5000 soil and 7000 water extracts for the calendar year. Each sample was subjected to QA/QC protocols, and comparisons with the external laboratory showed excellent agreement among the laboratories. The data base for each site has been developed to catalog the data for the project and to incorporate all QA/QC information. Only minor changes are being made in the operating procedures to permit a more rapid analysis of priority samples.

IOWA DEVELOPMENT OF FARMING MANAGEMENT SYSTEMS TO IMPROVE WATER QUALITY. J. L. Hatfield, T. B. Moorman, and T. R. Steinheimer, all USDA-ARS. Report Period: 3/90 - 2/92. Measurements made on the water flow and temperature patterns within a ridge-tillage and chisel-plowed system showed that the placement of chemicals in the ridge would be subjected to different leaching patterns in the ridge system. Nitrogen management systems need to be developed which account for realistic rather than overly optimistic yield goals and the soil survey reports could be used to develop yield goals. Placement of the chemicals within the upper soil profile and the distribution of these materials after a rainfall and throughout a growing season provide an understanding of the limits to which the system can be modified. These response characteristics are being studied with continued experimentation.

IOWA EVALUATION OF THE IMPACT OF CURRENT AND EMERGING FARMING SYSTEMS ON WATER QUALITY. J. L. Hatfield, USDA-ARS, Ames, IA, J. L. Baker, Iowa State University, and P. J. Soenksen, USGS, Iowa City, IA, MSEA Project. Report Period: 3/90 - 2/92. Field studies continued at all of the Iowa sites and the instrumentation was completed at each site to permit a complete array of observations. Herbicide concentrations in surface runoff showed high values during peak flow, and farming practices which reduced runoff also reduced pesticide movement. Concentrations of herbicides in tile drainage water were higher in the spring and early summer and modifications in application rates or times could improve the quality within the tile drain. Efforts are being made to assemble a complete data base for all of the parameters collected in the project and to relate these to landscape changes in water quality. A GIS approach to combine the observations and simulation models is being completed.

IOWA TRANSPORT AND CHEMICAL TRANSFORMATION OF PESTICIDES IN AGRICULTURAL SYSTEMS. J. L. Hatfield, T. B. Moorman, and T. R. Steinheimer, USDA-ARS, Ames, IA. Report Period: 2/90 - 2/92.

Concentrations of atrazine, metolachlor, and metribuzin residues were measured in soil profile samples from Walnut Creek and Treynor watersheds. Atrazine and the metabolites desethyl- and

desisopropyl-atrazine (DEA and DIA) were detected in lysimeter and tile flow samples under no-till corn. Concentrations of DEA were generally greater than DIA. Other laboratory experiments were begun to examine the kinetics and pathways of alachlor degradation in soils, aquifer samples and microbial cultures. A screening experiment showed that the ability to degrade alachlor is widespread among soil fungi. Further studies will determine the factors limiting the activity of these isolates.

IOWA DECISION AID SYSTEMS FOR FARMING MANAGEMENT AND WATER QUALITY. D. B. Jaynes, J. L. Hatfield, and S. D. Logsdon, USDA-ARS. Report Period: 8/90 - 2/92.

Ponded and tension infiltration measurements indicated surface seal effects due to residue placement differences under different tillage systems. No-till had more rapid ponded infiltration than moldboard and chisel after heavy spring rains. Differences related to crop rotation and landscape position were not clear cut. Infiltration at water pressure heads of -3 and -6 cm increased over the season. Vertical worm channels below 55 cm depth resulted in faster vertical saturated conductivity relative to horizontal on a Kenyon Loam. Large surface cracks also contributed to rapid infiltration under ponded conditions. A post-doctoral position was filled to develop models of water and chemical transport through macropores.

IOWA IMPACT OF PREFERENTIAL FLOW ON CHEMICAL AND WATER MOVEMENT IN AGRICULTURAL SYSTEMS. D. B. Jaynes, S. D. Logsdon, and J. L. Hatfield, USDA-ARS. Rpt Period: 8/90 - 2/92.

In situ ponded and tension infiltration measurements were made at the three MSEA sites in Iowa at surface and near surface depths. The measurements were used to characterize different tillage systems, crop rotations, and landscape positions over time. Deep soil cores were taken at the Treynor deep loess site to measure the distribution of nitrogen, pesticides, and microbial activity with depth. Results from a chemigation study of a surface irrigated field showed that nitrate application in the irrigation water causes significantly greater leaching losses as compared to surface spray application prior to the irrigation (increased preferential flow).

IOWA GROUNDWATER RECHARGE AND CHEMICAL TRANSPORT IN TWO GLACIAL TILL CONFINING UNITS IN IOWA. R. S. Kanwar, W. W. Simpkins, R. O. Horton, T. E. Fenton, L. C. Jones, J. L. Baker, Iowa State Univ and G. R. Halberg, Iowa Dept of Nat Res, Iowa City, IA. Rpt Period: 7/90 - 2/92.

A large vertical borehole cavity (3.15 m in diameter by 3.3 m deep) and a system of lateral suction lysimeters has been installed at the Ames site. The system has been used to collect water samples from the saturated and unsaturated portions of the soil profile. Rainfall events and rainfall simulation events will be used to gain an understanding of chemical transport by preferential and unsaturated flow in the vadose zone. Water quality data from monitoring piezometers located throughout the field indicate pesticide concentrations below the detection limit and nitrate-nitrogen concentrations of less than 1 mg/l below a depth of 4.5 m. Data on subsurface drainage water indicate that split N-fertilizer application reduces $\text{NO}_3\text{-N}$ concentration in the tile effluent.

KENTUCKY IMPACT OF RIPARIAN VEGETATION ON WATER QUALITY: MODELING AND MEASUREMENT. B. J. Barfield, R. Blevins, V. P. Evangelou, D. I. Carey, A. W. Fogle, University of Kentucky, Lexington, KY. Report Period: 5/1/90 - 2/1/92.

Field studies on water quality impacts of natural riparian vegetation have been completed as planned with laboratory analysis of samples nearing completion. Two remaining tasks are: 1. complete the models of sedimentation in natural grass vegetation, accounting for the effects of channelization and 2. complete the model of trapping of atrazine and phosphorous in natural vegetative filter strips (VFS). Strips of 15, 30 and 45 ft were established in naturally occurring riparian fescue where microchannels were likely to develop. Their effectiveness in trapping sediment, atrazine, phosphorous and nitrogen was evaluated. Results for tests analyzed to date show high trapping percentages.

KENTUCKY THE ROLE OF SEDIMENT IN NUTRIENT TRANSPORT IN A KARST GROUND WATER CATCHMENT. G. K. Felton, W. W. Frye, University of Kentucky. Report Period: 7/91 - 1/92. Field installation is proceeding according to schedule with the exception of obtaining land owner permission for one surface water sampling site. An alternate site is being investigated. Storm event sampling and analysis (4 hr sampling interval) at Owen's karst window and Garrett's spring was initiated with a storm on 8/28/91. The results were presented at the 1991 Annual Winter meeting of the ASAE. The most pertinent results based on three low flow events are: 1) nitrate concentration in the spring drops in response to precipitation, 2) calcium mass flow rate responds non-linearly with time resulting in a relationship that may aid hydrograph separation work, 3) flow through the karst conduit system resulted in increased nitrate concentration at the spring, and 4) flow through the karst system resulted in reduced solids, indicating deposition and storage were occurring in the underground conduit system. In general, during low flow events, the karst conduit system stores solids and releases stored chemicals.

LOUISIANA PERCEPTIONS OF WATER QUALITY PROBLEMS AMONG RURAL RESIDENTS OF THE SOUTHWEST LOUISIANA IRRIGATED RICE PRODUCTION REGION. E. J. Luzar and G. W. Wilkerson, Louisiana State University. Report Period: 5/90 - 2/92.

Well data incorporated in a geographic information system for the Chicot Aquifer in Southwest Louisiana for use in economic and spatial analysis include agricultural use for irrigation, rural domestic use, and agricultural use for aquaculture. In addition to ground water problems related to chloride (salt-water) intrusion in the Chicot Aquifer region, presence of excessive suspended solids was identified as a primary surface water quality problem. As a result, water quality data from regional surface water monitoring stations were also entered into the GIS database for temporal and spatial analysis. Tasks which remain include administration and analysis of the attitudinal main surveys and estimation of willingness-to-pay values for changes in water quality.

LOUISIANA ATRAZINE IN THE SOIL ROOT ZONE AND QUALITY OF GROUNDWATER OF SHALLOW WATER-TABLE SOILS. H. M. Selim, D. C. Johnson, and L. Ma, Louisiana State University Agricultural Center and L. M. Southwick, G. H. Willis, USDA-ARS. Report Period: 8/90 - 2/92.

The objective of this study is to quantify the mobility of atrazine in clay soils with a shallow water table. Sugarcane plots on Sharkey soil with drains with spacings of 6 and 12 m were used. All drains are located at 1 m depth below the soil surface. Atrazine was applied in June followed by another application in December (1990). Results following the June application showed a sharp rise in effluent concentration followed by a slow decrease for a period of two months. Maximum effluent atrazine concentrations associated with June application were 82 and 403 ppb for the 6 and 12 m spacing, respectively. Maximum concentrations associated with the winter application were 165 and 82 ppb, respectively. Atrazine applications were made in June and December 1991 and mobility of atrazine was monitored using solution samplers and drain outflow. Transport experiments were conducted on columns of Sharkey soil using ¹⁴C-labeled atrazine. Several aggregate size fractions were used to investigate the prediction capability of multi-domain solute transport models.

LOUISIANA WATER MANAGEMENT FOR IMPROVED GROUNDWATER QUALITY AND FARM CHEMICAL USE EFFICIENCY. G. H. Willis, J. L. Fouss, J. S. Rogers, C. E. Carter, L. M. Southwick, USDA-ARS, Baton Rouge, LA. Report Period: 1/89 - 2/92.

The construction/installation of 16 watertable control plots will be completed in summer of 1992. Application of 4 watertable management variables will be initiated in the fall of 1992, and measurements of their effects on agrochemical transport in surface runoff and infiltrated water will begin with the 1993 cropping season. Development of water management strategies (models for automated subdrainage and subirrigation in relation to agrochemical application schedules) for using watertable control to improve water quality and farm chemical use efficiency will begin with the collection of the first year's data.

MAINE & NEW HAMPSHIRE IMPACTS OF PRECOMMERCIAL THINNING AND FERTILIZATION ON WATER QUALITY. R. D. Briggs, University of Maine, J. W. Hornbeck, USDA Foreign Service, C. T. Smith, University of New Hampshire. Report Period: 5/91 - 2/92.

Twenty-seven 10 m X 10 m plots, distributed over three soil drainage classes, were installed in dense areas of spruce-fir regeneration. Three treatments were randomly assigned (control, precommercial thinning (PCT), and PCT plus fertilization). Ceramic cup soil solution samplers were installed at 25 and 50 cm below soil surface, except for poorly drained plots where solum thickness limited installation to the 25 cm depth. Seven wells (depth ranging from 2.3-8.5 m below soil surface) were installed over the watershed. Height and diameter of trees on each plot were measured, crop trees were identified, and PCT treatments were applied. Solution samples were obtained from 45 lysimeters, 7 wells, and 6 stream sampling points in September and October 1991. Wells and streams were sampled again in November 1991 and January 1992. Monthly sampling for the 1992 growing season will begin April, 1992.

MARYLAND USDA-ARS PESTICIDE PROPERTIES DATABASE. B. Acock and P. Laster, Systems Research Laboratory and A. E. Herner, Environmental Chemistry Laboratory, ARS, NRI, Beltsville. Report Period: 1/91 - 3/92.

The ARS Pesticide Properties Database (PPD) is a compendium of chemical and physical properties of widely used pesticides. To the original 92 compounds in the database, about 140 compounds, as well as added data on the original 92, have been added from the SCS/ARS/SEC Database (D. Wauchope, ARS, Tifton, GA). We have focused on 19 of the most important properties impacting groundwater and atmospheric quality. In cooperation with the National Agricultural Chemicals Association (NACA) we have been provided with manufacturers original experimental data. This provides the basis for the PPD, which is augmented with data from the scientific literature and handbooks. All data points are referenced and the references are characterized.

MARYLAND PREDICTION OF GROUNDWATER CONTAMINATION FROM GENETICALLY ENGINEERED MICROBES. J. S. Angle, R. L. Hill, University of Maryland. Report Period: 6/90 - 2/92.

Leaching of genetically engineered microbes through soil is a significant concern related to groundwater quality. The purpose of this study was to examine the leaching, survival, and gene transfer of a genetically engineered microbe in an undisturbed soil column. *Pseudomonas aeruginosa* PA025, containing the plasmid R68.45, was added to the surface of undisturbed soil columns and the columns leached with water. Leachate was analyzed daily for the presence of donor and transconjugants. No donor or transconjugants were detected in the leachate at any time period. Periodically, cores were dismantled and sectioned by depth. After a slight increase, the donor population in soil decreased by both depth and time. Low numbers of transconjugants were present and also decreased with depth and time. These results show the importance of examining leaching and survival of both donor and transconjugant populations in soil.

MARYLAND DEGRADATION OF PESTICIDE WASTE BY OZONE AND MICROBIAL METABOLISM. C. J. Hapeman-Somich, D. R. Shelton, USDA-ARS, Beltsville, MD. Report Period: 7/90 - 2/92.

An urgent need exists for safe, cost effective technologies to dispose of pesticide wastes, including unusable rinsates, spills, outdated or cancelled stocks, and contaminated soils. A binary system, involving chemical pretreatment (ozonation) and microbial mineralization, has shown promise in laboratory and field tests. Development and optimization studies have focused on the recalcitrant s-triazine herbicides. The chemical degradation pathway has been elucidated and a microorganism isolated that is capable of mineralizing the products under simulated field conditions. Based on these results, a more efficient unit, amenable to a variety of chemical and microbial treatment strategies, has been fabricated.

MARYLAND MINIMIZING THE EFFECT OF MACROPORE FLOW ON PESTICIDE LEACHING. A. R. Isensee, A. M. Sadeghi, T. J. Gish, W. J. Rawls, USDA-ARS. Report Period: 1/91 - 2/92.

Effect of pesticides applied to the surface of no-till (NT) and conventional-till (CT) fields on pesticide leaching was evaluated. Results indicated that if rain occurs soon after application, that much more leaching (through macropores) to shallow groundwater (<3 m depth) occurs under NT than CT. A laboratory experiment conducted to evaluate the impact of earthworms on macropore

formation and water infiltration indicated that most of the water flow occurred through only a few of the worm holes. An apparatus to measure leaching through intact soil cores was constructed and evaluated. The apparatus can be used to rapidly evaluate soil-water-pesticide interactions as they affect pesticide leaching.

MARYLAND SPATIAL AND TEMPORAL DISTRIBUTION OF AIRBORNE ORGANIC CONTAMINANTS IN WET AND DRY DEPOSITION. W. E. Johnson and C. S. Schomburg, USDA-ARS, Beltsville, MD. Report Period: 3/91 - 3/92.

Pesticide partitioning between air/water and water/water-dissolved organic material (DOM) was investigated. DOM decreased extraction efficiency of several pesticides from water but the effect was pesticide dependent. Air/water partition coefficients for pesticides in water samples containing DOM are in some cases an order-of-magnitude lower than values in pure water, indicating an aqueous phase enrichment. Photolysis of several pesticides in laboratory solutions containing nitrate ion or estuarine river water indicated that nitrate enhances the rate of photolysis of alachlor and chlorpyrifos. Chlorpyrifos rapidly photodegraded in estuarine river water, while alachlor did not.

MARYLAND & IDAHO NUTRIENT MANAGEMENT EXPERT SYSTEM. H. Lemmon, B. Acock, USDA-ARS, Beltsville, and J. Bartulovitch, University of Idaho. Report Period: 2/91 - 2/92.

NUMEX is an expert nutrient management system for use in soil testing laboratories. It accumulates data on the nutrient content of soil samples submitted by farmers for analysis, and on the manure and sludge available for field application. Recommendations are then made to the farmer for fertilizer, manure and sludge application. The principal objective is to feed the crop while preventing the build-up of heavy metals in the soil, and preventing the contamination of surface and ground water, especially by nitrates. NUMEX was developed originally for the University of Maryland, and this project is to adapt it for use in the mid-West. Collaboration has been established with Drs. Voss and Killorn, Iowa State University, and Drs. Schepers and Frank, University of Nebraska. The rules for the original NUMEX have been examined by the collaborators for applicability in their state, and modifications and new rules proposed. Information on hardware availability and requirements for data input and output have been recorded. Coding of the expert system will follow.

MARYLAND EFFECT OF N PLACEMENT AND RIDGE TILLAGE ON NITRATE LEACHING AS TRACED BY BROMIDE. R. R. Weil and A. Shirmohammadi. Univ of MD, College Park. Rpt Per: 7/91 - 1/92.

Using established no-till (NT) or ridge-till (RT) corn plots in a corn/soybean rotation, we installed three grids of tensiometers, each with 5 banks of 6 instruments set from 15 to 90 cm deep. We installed two similar grids of 30 suction lysimeters each, 1.5 m on both sides of each tensiometer grid. Lysimeters were made of 1.2 cm ID PVC with a porous ceramic tip and sample access and vacuum tubes. Tensiometers were fitted with a rubber septum cap for use with a transducer-equipped 'tensimeter'. Some soil water samples were obtained beginning in August, but due to extremely dry conditions, complete sets were not obtainable until November. Ion chromatograph peaks for Br⁻¹ and NO₃⁻¹ ions partially overlapped, but were sufficiently separated to obtain good standard curves using values for peak heights rather than peak areas. Preliminary data shows some horizontal trends in Br⁻¹ and NO₃⁻¹ concentrations, but a high degree of spatial variability in all systems. Concentrations of Br⁻¹ and NO₃⁻¹ were highly correlated ($r=.88$). Determination of Br⁻¹ and NO₃⁻¹ in lysimeter and soil core samples is currently underway and a leaching study is being set up using a mechanical vacuum extractor to determine the anion and cation exchange properties of the soils and compare the adsorptive behavior of the Br⁻¹ and NO₃⁻¹ anions.

MASSACHUSETTS & CONNECTICUT REGULATIONS AND ECONOMIC INCENTIVES FOR ACHIEVING GROUNDWATER QUALITY. C. R. Harper, C. E. Willis, J. T. Finn, University of Massachusetts, K. Segerson, University of Connecticut. Report Period: 7/91 - 2/92.

Major sources of groundwater contamination in a mixed land use setting are being investigated along with possible policy remedies. Land use data for southern New England have been developed in a Geographical Information System (GIS) format and are being refined to a crop-specific level.

Data on site characteristics, including soils, are in progress. To model economic responses to taxes and other incentives, a regional supply and demand model for major crops and agricultural inputs is being developed. When completed, the combined physical and socioeconomic models will permit comparisons of the costs and effectiveness of alternative protection policies.

MASSACHUSETTS DAIRY MANURE ON ALFALFA TO REDUCE OVERAPPLICATION AND N LOSS FROM CORN FIELDS. S. J. Herbert, J. Daliparthi, P. L. M. Veneman and J. Moffitt, University of Massachusetts. Report Period: 6/90 - 2/92.

Applying dairy manure to alfalfa as an alternative to excess application to corn can reduce nitrate pollution of ground water. Water samples collected in suction lysimeters at 30, 60, 90 and 120 cm depth at two sites had significant amounts of $\text{NO}_3\text{-N}$. Covariance was high among treatments, sampling depths and the sampling dates. There was no difference in $\text{NO}_3\text{-N}$ concentrations in leachate from low (112 kg N ha^{-1}) manure and control plots, whereas high (336 kg N ha^{-1}) fertilizer and high manure (2nd year) showed significantly more $\text{NO}_3\text{-N}$ in leachate than the control. Manure application to alfalfa neither reduced forage yield nor increased weeds. More research is needed on leachate through macropores and residual effects of manure on long-term nitrate leaching. These preliminary results indicate farmers could apply manure to alfalfa at rates of 20 to 30 ton/acre without an adverse effect on ground water quality and without economic risk.

MICHIGAN, PENNSYLVANIA & MINNESOTA ASSESSMENT AND MODELING OF NITRATE LEACHING UNDER CONVENTIONAL AND ORGANICALLY MANAGED CORN. E. A. Paul, P. Grace, G. H. Harris, O. B. Hesterman, J. T. Ritchie, K. Paustian, Michigan State University, S. E. Peters, R. R. Janke, K. Kroll, Rodale Inst, J. A. E. Molina, Univ of Minnesota. Report Period: 7/90 - 2/92.

Natural drainage lysimeters were installed in a long-term cropping system experiment at the Rodale site in October 1990. Nitrate-N leached from animal-, legume green manure- and fertilizer-based cropping systems for October 1990 to May 1991 measured 22, 15 and 11 kg ha^{-1} , respectively. Loss of N by nitrate leaching was also highest in the animal-based system from May-October 1991, but was relatively low for all three cropping systems. Results suggest that the method of manure application used in this study needs reevaluating and nitrate leaching may not be the main mechanism of N loss at this site.

MICHIGAN & KANSAS STRATIFICATION AND FATE OF N WITHIN SOIL PROFILES: MANAGEMENT-INDUCED CHANGES. F. J. Pierce, J. R. Crum, B. D. Knezek, Michigan State University and C. W. Rice, M. D. Ransom, and R. E. Lamond, Kansas State University. Report Period: 4/90 - 3/91.

Drought and adequate rainfall years occurred in alternating years at Michigan and Kansas. Corn responded to N applications only in the dry year at Kansas and the adequate rainfall year at Michigan. No $\text{NO}_3\text{-N}$ leaching occurred at Kansas, but high solution concentrations ($> 50 \text{ ug m}^{-1}$) were measured at Michigan during the non-crop period, with higher concentrations in soybeans than corn and in ridge-till than other tillage systems. Manure increased denitrification potential by 6 times over fertilized treatments and increased soluble C at depth in Kansas. Tracer studies this year will quantify effects at stratification, row position, and preferential flow.

MINNESOTA A FIELD TRACER TEST METHOD FOR LARGE SOIL SAMPLES. E. C. Alexander, Jr., J. L. Nieber, University of Minnesota. Report Period: 6/91 - 2/92.

Large diameter tree transplanting equipment is being tested for use in a new method of measuring flow in the unsaturated zone. Tree transplanting equipment is widely available and in minutes can excavate a two cubic meter volume soil sample without obvious soil disturbance. The method entails the temporary excavation of a soil sample using the tree transplanter then returning the sample to the same hole after the installation of a sump and a funnel shaped impermeable liner. Tracer tests can then be carried out by applying water at the surface, and sampling from the sump using an automatic sampler. This methodology generates discharge-time-solute concentration data on a one minute time interval and is therefore ideal for studying rapid flow processes through soils. The experimental isolation of equipment effects, and a full analysis of soil sample

disturbance in a variety of soils are major goals of the remainder of this project. The method has the potential to be a rapid, practical and cost effective means of measuring both porous-media and preferential flow effects in the unsaturated zone.

MINNESOTA, WISCONSIN, N DAKOTA & S DAKOTA NORTHERN CORNBELT SAND PLAINS

MSEA. J. L. Anderson, University of Minnesota; R. H. Dowdy, USDA-ARS, St. Paul, MN; and G. N. Delin USGS, St. Paul, MN, **MSEA Project.** Report Period: 7/90 - 2/92.

Field experiments were established at one main location (Princeton, MN) and three satellite sites (Oakes, ND; Aurora, SD; and Arena, WI) in 1991. Initial soil and aquifer characterization data were collected. The common farming system at all locations is a corn-soybean rotation using ridge tillage, band application of atrazine/metolachlor and alachlor, split N application, and irrigation scheduling. Two additional systems were established at Princeton, continuous corn and potato-sweet corn rotation. Continuous corn has full width tillage, broadcast application of atrazine and alachlor, split N application, and excess irrigation water. Potato production has full width tillage, broadcast application of metribuzin and metolachlor, split N application, and irrigation scheduling. Sweet corn is managed similar to corn in the corn-soybean rotation. The N application amounts for 1991 were 224 kg N/ha for potato, 156 kg N/ha for corn, and 0 kg N/ha for soybean. Forty-four water monitoring wells were installed and sampled for pesticides, nitrate, and water level. Soil spatial variability is being evaluated by both soil survey and grid sampling of crop yields in each area.

MINNESOTA DEVELOP ALFALFA TO INCREASE N₂ FIXATION AND REDUCE NITROGEN LOSSES TO THE ENVIRONMENT. D. K. Barnes, M. P. Russelle, J. F. Lamb, and C. P. Vance, USDA-ARS, St. Paul, MN. Report Period: 2/91 - 2/92.

Plans and facilities for this new project were developed and a new plant geneticist/plant physiologist hired. Experiments were initiated to: 1. Evaluate the dynamics of root growth and senescence utilizing minirhizotron methodologies; 2. compare rate and depth of soil nitrate removal by effectively and ineffectively nodulated plants grown on an abandoned manure application study having varying amounts of subsoil nitrates (about 280 to 2800 kg N/ha); 3. evaluate yield and BNF of alfalfa germplasms selected for NO₃ reductase and nodule effectiveness when fertilized with ammonium nitrate; 4. evaluate the effects of bidirectional selection for alfalfa nodule enzymes, nodule fresh weight, nodule soluble protein concentration; and shoot dry weight; and 5. breed special purpose alfalfas that can be used to improve energy efficiency of crops grown in rotation, to improve N cycling when manures are applied and to remove nitrate from below the root zone of cereal crops.

MINNESOTA EFFECTS OF SOIL FREEZING ON THE FATE OF SOIL APPLIED NITROGEN AND PESTICIDES. G. R. Benoit, J. A. Daniel, J. A. Staricka, USDA-ARS, Morris, MN. Report Period: 1/90 - 2/92.

A two phase field study continues to evaluate frost-landscape effects on winter movement of nitrate and atrazine to surface and ground water. In phase one, data from a grid of 15 groundwater observation wells and an instrumented leg of a transect through a field depression has shown lateral flow of water to the depression and rapid development of a groundwater recharge mound under the depression during runoff from thawing soil events. In phase two (located in depression 2), data from 4 tillage residue systems, each split with two levels of nitrogen and atrazine show frost induced soil water movement plus both lateral and vertical movement of nitrate and atrazine.

MINNESOTA SORPTION-DESORPTION PROCESSES AFFECTING PESTICIDE MOBILITY IN TILLED SOILS. C. E. Clapp, R. R. Allmaras, D. R. Linden, W. C. Koskinen, J. M. Baker, R. H. Dowdy, USDA-ARS, St. Paul, MN. Report Period: 7/90 - 2/92.

Tillage and methods of incorporating agrichemicals can significantly influence the escape of agrichemicals from their target position. The depth for incorporation of agrichemicals is predictable, but research now reveals how tillage and crop residues can influence the local environment of the incorporated agrichemical. A study was conducted to determine the effect of surface microrelief, microlandscape position, and rainfall intensity on water and solute transport in burrows created by earthworms. Models designed to predict flow in burrows must consider quantity of water available to, and flow within, a burrow. In laboratory experiments, desorption

coefficients were dependent on adsorbed atrazine concentration. For field-aged residues, desorption (K_1) values increased slightly with time. However, values were lower than would be predicted if based on laboratory data where equal adsorbed concentrations were compared. It is necessary to take into account the change in the atrazine-soil interactions with aging.

MINNESOTA WEED EMERGENCE MODELING FOR A WEED/CROP BIOECONOMIC EXPERT SYSTEM. F. Forcella, G. R. Benoit, USDA-ARS. Report Period: 1/90 - 2/92.

The Weed/Crop Bioeconomic Management Expert System, known as WEEDSIM, is being developed for the U.S. Corn Belt by a large team of economists and scientists from USDA and state experiment stations. WEEDSIM provides a basis for rational weed management decisions, and its use typically results in lower herbicide use in both corn and soybean crops. For the expert system to function properly, the timing and extent of weed seedling emergence in spring and early summer must be predicted. Simple and user-friendly computer models that make such predictions accurately have been developed for five important Corn Belt weed species. Models for other important weeds currently are in progress.

MINNESOTA & IOWA ROLE OF EARTHWORM MACROPORES IN PREFERENTIAL FLOW OF WATER AND CONTAMINANTS. S. C. Gupta, J. F. Moncrief, E. Munyankusi, A. Bhattacharjee, University of Minnesota, and É. C. Berry, USDA-ARS, Ames, IA. Report Period: 9/91 - 2/92.

Experiments are in progress to quantify the effects of nitrogen source on the distribution and continuity of soil macropores formed by earthworms. Six undisturbed cores (30 cm dia. by 100cm long) were taken from a field experiment with a continuous eight year history of inorganic N fertilizer or liquid dairy manure application. Earthworms collected at the time of core excavation showed that *Aporrectodea tuberculata* is present in the inorganic fertilizer plot whereas *A. tuberculata*, *A. trapezoides*, *Lumbricus rubellus*, and *L. terrestris* are present in the plot that received liquid dairy manure. Cores are being used to characterize water flux, macropore number, size distributions and continuity both by running breakthrough curves, paint injection techniques and image tracing of visible macropores at various depths. Image traces are being used to reconstruct cores on a computer screen to visually assess the continuity of macropores. Data will be analyzed with respect to the differences in earthworm specie on macropore continuity.

MINNESOTA & NEBRASKA INTEGRATION OF N MANAGEMENT ALTERNATIVES TO MINIMIZE GROUNDWATER CONTAMINATION. G. Malzer, P. Robert, D. Baker, J. Moncrief, R. Levins, University of Minnesota. G. Hergert, D. Martin, D. Watts, University of Nebraska, J. Schepers, USDA-ARS, Lincoln, NE, and R. Beck Cenex/Land-O-Lakes, St. Paul. Rpt Period: 8/89 - 2/92.

Expert systems are being developed within each state that would allow for site specific N fertilizer recommendations that are economically and environmentally sound. Teams from Minnesota and Nebraska have met on a regular basis to coordinate activities and to define conditions for site specificity, economic and environmental concern, and economic and logistical feasibility. Prototype expert systems have been developed and are currently being evaluated. The expert systems will utilize either soil information provided by the user, or will access site specific information from a digitized soil map and associated soil survey information. The latter feature will allow easy adaptability for variable N rates on-the-go. The site specific soil information is used along with user management information to determine the minimum rate of fertilizer N needed for production. Both components are integrated together to provide management recommendations that will minimize N loss during the growing season.

MINNESOTA ISOPOTENTIAL ION EXTRACTION OF PESTICIDES. A. Olness, N. T. Basta, USDA-ARS, Morris, MN. Report Period: 1/90 - 2/92.

US Patent 4, 816,161 was successfully modified using teflon components and XAD-2 resin for routine extraction of pesticides from soil suspensions and solutions. Extractions were effected over a broad range of soil types and environmental conditions. The extractor is capable of simultaneously extracting atrazine, metribuzin, and alachlor. An accurate and precise method has been developed which permits inexpensive extraction of large numbers of samples. Extractor eluates are injected directly into GC systems without costly cleanup procedures. Initial results

show similar pesticide recoveries under both aerobic and anaerobic conditions. Detection limits are 1 to 5 ng g⁻¹. Extraction conditions ($\geq 25^{\circ}\text{C}$ in 20% methanol) inhibit microbial decay and speed extractions.

MINNESOTA, IOWA & WISCONSIN REGIONAL ASSESSMENT OF SOIL NITROGEN TESTS IN IOWA, MINNESOTA, AND WISCONSIN. G. W. Randall, M. A. Schmitt, University of Minnesota, R. J. Killorn, R. Horton, M. Duffy, Iowa State University, and L. G. Bundy, P. Nowak, University of Wisconsin. Report Period: 5/91 - 2/92.

Thirty five field studies were conducted to assess soil N tests over a wide range of soil/climatic/crop conditions. Thirteen sites did not respond to fertilizer N. The pre sidedress soil nitrate test (0-1' sample) did not differentiate between responsive (R) and non-responsive (NR) sites in any state. Differentiating R from NR sites was improved when taking a 0-2' or 0-3' sample at the preplant or emergence stage and determining nitrate. Ammonium or potentially available organic N data did not improve soil test relationships but separation into parent material classes did. No testing method performed well when alfalfa was the previous crop.

MISSISSIPPI IMPROVE WATER QUALITY BY DEVELOPMENT OF MORE EFFICIENT METHODS OF APPLYING HERBICIDES. J. E. Hanks, C. G. McWhorter, and K. D. Howard, USDA-ARS, Stoneville, Mississippi. Report Period: 2/91 - 2/92.

Nozzles were identified for the air-assist system that provided uniform spray distribution when applying herbicides in paraffinic oil or water. Adjuvants to reduce the number of small droplets ($<100\ \mu$) were identified for both paraffinic oil and water. A device was invented to uniformly divide the liquid flow from a single pump to multiple spray nozzles. Clethodim herbicide applied at ultra-low-volume (ULV) in paraffinic oil decreased foliar wash off with rainfall as compared to conventional spray volumes in water. Evaluation of air-assist, ULV spray technology was initiated on a national basis by application of standardized field experiments in six other states. Research was initiated with sensor controlled intermittent sprayers that detect the presence of weeds and turn individual nozzles on/off as needed.

MISSISSIPPI, IOWA & TENNESSEE COTTON IRRIGATION AND THE EFFECTS ON HERBICIDE MOVEMENT, PERSISTENCE, AND CARRYOVER. C. E. Snipes, H. C. Pringle III, Mississippi State University, T. B. Moorman, Ames, IA, M. A. Locke, Stoneville, MS, USDA-ARS, and T. C. Mueller, University of Tennessee. Report Period: 4/90 - 2/92.

Adsorption and degradation of fluometuron were determined in soil from different depths of a Beulah silt loam profile. After the addition of 1450 ng fluometuron/g soil, degradation was adequately described by pseudo-first-order kinetics. However, these kinetics did not describe degradation after addition of 85 ng/g of [¹⁴C] fluometuron. At this lower concentration, degradation rates decreased as soil depth increased, but rates were not strongly correlated with either soil adsorption coefficients (K_d) or biomass. Approximately 56% of adsorbed fluometuron was desorbed in a single equilibration step, suggesting that a large fraction of adsorbed fluometuron is available for degradation. Decreased adsorption and degradation rates in lower soil depths increase potential leaching.

MISSOURI ALTERNATIVE MANAGEMENT SYSTEMS FOR ENHANCING WATER QUALITY IN AN AQUIFER UNDERLYING CLAYPAN SOILS. E. Alberts, USDA-ARS, Columbia, MO, and A. Prato, N. Kitchen, University of Missouri, MSEA Project. Report Period: 3/90 - 2/92.

Recharge of the aquifer underlying claypan soils varies from very slow to rapid, indicating zones of focused recharge. Influences of soil cracks, claypan discontinuities, biopores, and other preferential flow paths are being studied. Concentrations of triazines and alachlor were generally below the detection limit (0.2 ppb) from baseline sampling of 100 ground water wells distributed over the 28 square mile Goodwater Creek watershed. Ground water NO₃-N concentrations varied considerably among fields within the watershed. Wells that contain NO₃-N concentrations $> 10\ \text{ug/l}$ are usually associated with pastured areas or cropped areas that received animal manures prior to 1980. Atrazine concentrations in streamflow, particularly during surface runoff

periods, are always above the minimum detection limit. Lateral flow, which results from rainfall infiltrating the soil and moving laterally over the claypan surface, had the highest NO₃-N concentrations of any water sampled in this hydrogeologic system.

MISSOURI TRIPSACUM AND OTHER CORN RELATIVES AS RESOURCES FOR OPTIMIZING PRODUCTION PRACTICES THAT AFFECT GROUND WATER QUALITY. E. H. Coe, Jr., B. D. Barry, L. L. Darrah, USDA-ARS, Columbia, MO; and C. A. Blakey, Univ of Missouri. Rpt Period: 2/91 - 2/92. Information has been accumulated via reprints, phone conversations, visiting scientists, and visits to key laboratories. Corn materials with potential resistance to rootworm, *Tripsacum*, and teosinte and products of crosses between corn and *Tripsacum* have been identified or obtained. Field equipment for rootworm infestation has been constructed. Protocols and techniques for screening under controlled seedling growth conditions are being tested or are under development. Greenhouse work included observations on corn, *Tripsacum*, and teosinte. Corn seedlings (European corn borer resistant) and one commercial *Tripsacum dactyloides* were readily killed by first instar larvae of the western corn rootworm. Other species of *Tripsacum* and other varieties of *T. dactyloides* from CIMMYT and ORTOSOM (France) scientists are under observation in the greenhouse. Data have been obtained for mapping restriction fragment length polymorphisms in an F₂ population between two parents of *T. dactyloides*, showing 19 linkage groups at this early stage from approximately 73 probed loci.

MISSOURI ROLE OF PLANT RHIZOSPHERE AND ASSOCIATED MICROFLORA IN PESTICIDES DEGRADATION. G. A. Buyanovsky, G. H. Wagner, University of Missouri, and R. J. Kremer, USDA-ARS. Report Period: 6/90 - 2/92.

In greenhouse experiments designed to assess the effect of plant systems on pesticide dissipation, new evidence of a complex interaction between roots, microorganisms, and xenobiotics has been discovered: 1) There were certain differences in carbofuran degradation subject to the closeness to corn roots. During the initial period of active plant growth (the first 30 days), the rate of degradation in close proximity to the roots was 1.5-2 times higher than in soil without roots. Later, no significant difference was found between the rhizosphere and the soil without roots. 2) A significant uptake and translocation of radioactive compounds (presumably carbofuran and degradation products) through the root system was detected. The highest concentration of absorbed xenobiotics was found in the corn leaves (14-32% of the total radioactivity applied to the soil), and the lowest was in the reproductive organs (0.12-0.16%).

MISSOURI MOVEMENT AND PERSISTENCE OF PESTICIDES IN HIGHLY AGGREGATED SOILS. C. J. Gantzer, G. A. Buyanosky, S. H. Anderson, S. Kapila, Univ of MO. Report Period: 7/89 - 2/92.

Transport of surface applied chemicals by percolating water was studied on a Menfro silt loam. Aldicarb and carbofuran were applied at 3 kg a.i./ha to 16 plots, 8 of which were near field capacity (wet) and the other 8 were near permanent wilting point (dry). Half of the dry and wet plots received irrigation immediately after chemical application and the other half received irrigation after 24 hrs. The transport and degradation parameters were estimated using CXTFIT. Estimated values of the dispersion coefficient, D, were higher for initially dry soil compared to initially wet. Estimated values for the retardation factor, R, for aldicarb were about 30% more than values whereas for carbofuran they were about 60% lower. To assess persistence of pesticides at depth in a soil, a laboratory incubation was done using ¹⁴C-labeled carbofuran and aldicarb. The top soil (0-30 cm) showed greater degradation rates than subsoil. The total amount of insecticides mineralized in the soil from the topsoil was 3-5 times greater than in the subsoil. The microbial community of the top of the soil has a much shorter adjustment time for added chemicals.

MISSOURI CT-MEASURED FRACTAL DIMENSION, LACUNARITY AND CRACK POROSITY RELATED TO TRANSPORT. R. L. Peyton, S. H. Anderson, C. J. Gantzer, J. U. Baer. University of Missouri-Columbia. Report Period: 9/91 - 2/92.

Materials of constant density containing simulated cracks of known width were fabricated and then were scanned by X-ray computed tomography (CT). This data will form the basis of the algorithm to quantify crack widths in soil cores from CT scans. A preliminary algorithm has been written to

take a digitized image of crack patterns and estimate the fractal dimension and lacunarity. Trial photographs of soil surface cracking have been taken under natural and controlled field conditions. Protocol for digitizing these photographs have been developed. Field studies have begun to study crack porosity. Fifty earth anchors have been installed in two claypan plots associated with the Missouri Management Systems Evaluation Area. Beginning this spring, weekly measurements will be made of vertical soil movement which will be converted into soil volume change and crack volume. Preliminary soil core breakthrough experiments have begun using Ct to relate small-scale dispersivity to fractal dimension and lacunarity.

MONTANA VALIDATION OF TRANSPORT MODELS FOR PREDICTING MOVEMENT OF AGRICHEMICALS THROUGH SOILS. W. P. Inskeep, A. H. Ferguson, R. H. Lockerman, J. W. Bauder, J. S. Jacobsen, Montana State University. Report Period: 9/89 - 8/91.

Field and laboratory experiments have been completed to determine the transport of herbicides and nitrogen under different moisture regimes. The solute transport model, LEACHM, adequately predicted the breakthrough of solutes at different soil depths. Results using dicamba indicate the importance of water management and timing for preventing unnecessary movement of dicamba into groundwaters. Results for NO₃-N indicate that adequate fertilization for expected yield goals and prudent water management will not result in excessive NO₃- movement into groundwaters. Fertilization under dryland conditions may result in NO₃- accumulation and transport out of the root zone. These results are currently being used to formulate recommendations concerning best management practices for agrichemical use in Montana.

MONTANA VALIDATION OF SOLUTE TRANSPORT MODELS UNDER VARYING MOISTURE REGIMES. W. P. Inskeep, S. D. Comfort, R. H. Lockerman, and J. S. Jacobsen, Montana State University. Report Period: 9/91 - 2/92.

Current efforts to validate the solute transport model, LEACHM, for predicting chemical movement under cropped and fallow conditions show good agreement between observed and predicted results. LEACHM adequately predicted Br and PFBA transport under three different water regimes at 36, 66 and 96 cm soil depths. Accurately measured hydraulic conductivity parameters (e. g. variables in the Campbell's equation) are critical to model success. Experiments will continue for two field seasons to evaluate the transport and fate of herbicides under field conditions with varying water regimes. Future work will compare additional solute transport models including CMLS and PRZM. We have several experiments in progress to study herbicide transport in soil columns under laboratory conditions, with emphasis on investigating factors contributing to nonequilibrium transport such as preferential flow and herbicide reaction kinetics. An understanding of these processes will aid in the interpretation of results obtained under field conditions.

MONTANA, MINNESOTA & MAINE A LAND AND MICROCLIMATE ON-FARM INFORMATION SYSTEM FOR GROUNDWATER PROTECTION. J. S. Jacobsen, G. A. Nielsen, J. P. Wilson, Montana State University, P. C. Robert, University of Minnesota, and D. A. Tyler, University of Maine. Report Period: 6/91 - 2/92.

A field site has been identified in cooperation with the Gallatin County Conservation District, Soil Conservation Service, Extension Service and local farmer input. Detailed elevation data with Global Positioning Satellites (GPS), multispectral digital imagery and preliminary soil analysis have been completed. Soil, terrain, microclimate, and imagery GIS maps that depict nutrient leaching will be tested and the capabilities of an on-farm GIS for managing contrasting environments within fields will be improved. Soil specific fertilization practices have increased small grain farmers set returns an average of \$2-4/ha. Intuitively, by matching fertilization practices with soil and climatic variability, plant utilization will be maximized and water quality will be minimized. The application of new technologies will integrate soil specific fertilization practices.

MONTANA CROPPING SYSTEMS AND NON-POINT SOURCE GROUNDWATER POLLUTION. J. Johnson, D. Griffith, J. Bauder, J. Jacobsen, J. Wilson, J. Antle, Mont State Univ. Rpt Per: 9/91 - 2/92. Summarization of the 3400 well water samples from the Montana well water data base was completed. This data base was combined with the existing Geographical Information database for

Montana to allow statistical modeling of spatial geographical information and well water survey results. The combination of the well water survey data and the Montana Agricultural Potential Systems (MAPS) was the first step towards tying water quality test results to a geographical database and allowing "predictions" of water quality problems using a GIS system. Preliminary site selection for field work was completed.

NEBRASKA MOVEMENT OF AGRICULTURAL CHEMICALS BENEATH CONSERVATION TILLED-FURROW IRRIGATED LAND. D. E. Eisenhower, R. B. Ferguson, F. W. Roeth, R. S. Spalding, University of Nebraska. Report Period: 7/91 - 2/92.

Advance time in furrow irrigation for four tillage and two cropping systems was measured. In a silt loam soil, there was an interaction between tillage and crop rotation. Conservation tillage slowed water advance in a continuous corn system but had no effect on advance in the corn/soybean rotation system. Core sampling was completed to 18 m in three tillage systems. Following collection, the 0.76 m plastic lined cores were frozen and stored. Indications from samples that have been analyzed are that nitrate-nitrogen accumulation in the vadose zone was significantly higher for the disk and surface plant system than for the ridge till and slot plant systems.

NEBRASKA QUANTIFYING NITRATE LEACHING UNDER CONTINUOUS CORN VERSUS A CORN-SOYBEAN ROTATION. G. W. Hergert, N. L. Klocke, D. G. Watts, J. P. Schnekloth, University of Nebraska, and J. S. Schepers, USDA-ARS, Lincoln, NE. Report Period: 9/91 - 2/92.

Because this project was just initiated, there are no results available at this time. The objective of this research is to quantify and compare nitrate-nitrogen leaching losses from a corn-soybean rotation versus continuous corn. Fourteen state-of-the-art 90 cm by 240 cm monolithic percolation lysimeters are in place. The cropping systems have been in place for 7 years with each phase of the rotation present each year. There are four replications of each treatment. Plots are 24 m x 24 m. The lysimeter installation has been fully tested and equilibrated in the field during the past year. Leaching did occur during 1991 and samples were analyzed for NO₃-N and total leachate volume. Data will be available after the first full year of the project in 9/92.

NEBRASKA MANAGEMENT OF SOIL, WATER, AND NITROGEN RESOURCES TO PROTECT GROUNDWATER QUALITY. J. S. Schepers, D. D. Francis, W. W. Wilhelm, and J. F. Power, USDA-ARS, University of Nebraska, Lincoln, NE. Report Period: 5/90 - 3/92.

A rapid and reliable method was developed to measure the nitrogen (N) status of corn plants during the growing season. The goal was to develop a procedure that would allow producers to monitor the crop and thereby evaluate the need for supplemental N fertilizer that could be applied with irrigation water or by other means. Initially, leaf disks (1-cm diameter) were used to determine N concentrations and compared with portable chlorophyll meter readings. Correlations between leaf disk N concentrations and chlorophyll meter readings were not universally acceptable because of problems related to different corn hybrids, stages or growth, and methods of fertilizer N applications. Agreement between the two methods was good for individual fields. Comparing leaf N status from an adequately fertilized part of the field with that from the rest of the field proved to be an excellent way to internally calibrate chlorophyll meters. In practice, this approach was able to detect crop N stresses and permit fertilizer application without reduction in yield.

NEBRASKA REAL-TIME MEASUREMENTS OF HERBICIDE PERSISTENCE IN GROUND WATER. Roy F. Spalding and Vitaly Zlotnik, University of Nebraska; Douglas M. Mackay, William W-G Yeh, and James F. Barker, University of Waterloo, Canada. Report Period: 4/91 - 2/92.

Data collection for the natural gradient herbicide injection test at Fremont, Nebraska is complete. A solution containing bromide, atrazine, metolachlor, alachlor, and cyanazine was injected on September 18 and monitored in 7 fences of multilevels over the next 2 months. This allowed for completion of the field work by one mixed injection. An agronomy Ph.D. graduate student is involved with this study. The 1343 pesticide and bromide analyses are presently being interpreted. Data collection for the induced gradient test at the Borden aquifer has also been completed. Six herbicides and chloride were injected. The preliminary interpretation of the data was included in an abstract of the 1991 fall meeting of the American Geophysical Union. Data from both studies suggests that atrazine is quite recalcitrant to degradation at normal ground water pHs.

NEBRASKA MANAGEMENT OF IRRIGATED CORN AND SOYBEANS TO MINIMIZE GROUNDWATER QUALITY. D. G. Watts, R. F. Spalding, and J. S. Schepers. University of Nebraska and USDA-ARS, Lincoln. MSEA Project. Report Period: 5/90 - 3/92.

Research was begun to evaluate the impact of management systems for monoculture irrigated corn, on groundwater quality in Nebraska's Central Platte Valley. These systems include conventional furrow irrigation and N management practices, surge flow irrigation and BMP N practice, and center pivot irrigation with fertigation timed through use of a chlorophyll meter. The surge and pivot systems reduced water application by 44% and 64%, while N amounts were cut by 39% and 83% with no yield loss. Twenty-five research projects were initiated under the MSEA project umbrella to develop new or improved BMP's for management of irrigation water and agrichemicals. Chlorophyll meter use and surge irrigation technology are being transferred to farmers.

NEW MEXICO CHEMICAL TRANSPORT AND PERSISTENCE IN A FURROW IRRIGATED NO-TILL MANAGEMENT SYSTEM. N. B. Christensen, J. Schroeder, T. L. Jones, New Mexico State University, J. M. H. Hendrickx, New Mexico Tech. Report Period: 5/91 - 2/92.

The project to study the transport and persistence of metolachlor under no-till and conventional till conditions was initiated in 1989. Characterizing the hydrological properties of the soil under the two tillage systems is currently under way. Metolachlor and organic tracers have been applied preemergence each year and soil samples collected throughout the season. Metolachlor dissipation from the conventional till and no-till areas have varied considerably. One dimensional transport simulations of bromide and metolachlor are currently being done using LEACHM, however no conclusive results are available at this time.

NEW YORK ELECTROCHEMICAL TREATMENT OF PESTICIDE WASTEWATER. A. T. Lemley, K. Pratap, Cornell University. Report Period: 6/90 - 3/92.

Electrochemical treatment of aqueous solutions of atrazine, metolachlor, alachlor, and picloram in laboratory experiments shows good promise for degradation of these wastes. An electrochemical Fenton's system that allows precipitation of ferrous iron in the presence of hydrogen peroxide at neutral pH values results in greater than 90% removal of the parent compound. Significant amounts of removal are due to degradation of the parent. The degradation follows first order kinetics in the pesticide, and products are observed as HPLC chromatographic peaks. Continued studies on formulated products and field samples containing the above herbicides (and cyanazine) and studies on degradation schemes will confirm the usefulness of this methodology in treatment of pesticide rinsates.

NEW YORK & MASSACHUSETTS REDUCING GROUNDWATER POLLUTION: A SYSTEMS ANALYSIS. C. A. Shoemaker and G. White, Cornell University and D. N. Ferro, University of Massachusetts. Report Period: 9/90 - 2/92.

The project objective is a holistic analysis of source control of pesticide pollution by evaluating the simultaneous effect of a given pesticide program on groundwater pollution, yields and economic return. The analysis will integrate three models describing the movement of pesticide into groundwater, the dynamics of an insect pest, Colorado potato beetle, the growth (given insect defoliation) of the potato crop. An insect model has been developed and is being modified to consider the effects of residual level of pesticide on pest survival rates. In summer 1991 field experiments were conducted to obtain these new rates. Residual activity (under field conditions) was determined by bioassay for M-One, M-One Plus, Asana, Vydate, Thiodan and Kryocide. In addition an improved weather generator has been developed and fit to study sites in the project. The insect model has been linked to a model of plant growth and to PRZM, a simulation model of pesticide movement. Preliminary results indicate that pesticide applications that are adjusted to the densities of pests in the field can provide more economic control with less groundwater pollution than pesticide applications that are applied on a fixed schedule.

NEW YORK INTERACTION OF PREFERENTIAL FLOW AND BIODEGRADATION IN HETEROGENEOUS SOILS. T. S. Steenhuis, M. Alexander, B. Pivetz, J. W. Kelsey, Cornell University. Report Period: 7/90 - 2/92.

The experiments involving biodegradation of organic substances in soils with preferential flow paths in small and large undisturbed columns are near completion. In these columns, macropore and matrix flows were sampled separately. Paranitrophenol (PNP) was used as the organic substance, as its concentration could be easily measured. The results show that, despite the fast flow through the macropores, the applied organic substances were always degraded after an initial adjustment period at which time the bacterial population increased. Finally, these experiments begin to explain why the aquifer is seldom contaminated in structured clay soils where preferential flow is prevalent and pesticides are transported downward to the groundwater.

NEW YORK & NEW MEXICO LOCATING SOIL LAYERS IN THE VADOSE ZONE WITH NONDESTRUCTIVE METHODS: ASSESSING VULNERABILITY TO CONTAMINATION OF AQUIFERS. T. S. Steenhuis, J.-Y. Parlange, L. M. Cathles, Cornell University; J. M. H. Hendrickx, J. Schlue, New Mexico Institute of Mining and Technology. Report Period: 8/91 - 2/92.

Knowledge of the location of the subsurface textural layers is important for assessing the potential of groundwater contamination and for locating solute samplers in the vadose zone. The hypothesis of this research is that ground penetrating radar, in combination with the electromagnetic induction method, provides a fast and nondestructive method for finding these layers, as proven in initial experiments in New Mexico and Delaware in light-textured soils. Research in the next two and a half years will further determine the limits of the proposed methods.

NEW YORK & MARYLAND PARAMETERIZATION OF TILLAGE EFFECTS ON SOIL HYDRAULIC PROPERTIES AND AGRICHEMICAL LOSSES. H. M. vanEs, J. L. Hutson, Cornell University, and R. L. Hill, University of Maryland. Report Period: 10/91 - 2/92.

Four experimental sites have been selected. The New York sites are located on Honeoye-Lima silt loam soil (Glossoboric Hapludalfs), which is representative of Western New York corn growing region and Rhinebeck clay loam soil (Aeric Ochraqualf) which represents the fine-textured soils in Northern New York. Both sites were used for alfalfa-grass production. Undisturbed soil cores were obtained and are being analyzed for soil water characteristic curves and saturated hydraulic conductivity. In Maryland, two sites were chosen on Bertie-Mattapex silt loam soils (Aquic Hapludults) in Wye Mills, MD which are representative of Maryland's Eastern Shore. One site has been in continuous corn under conventional and no-till management since 1988. The second site has been cropped to soybeans and will be established in spring 1992 and is located under an overhead tract irrigation system to allow for controlled rainfall application. Soil infiltrometers and portable rainfall simulators are being constructed. The LEACHM model has been adapted to include preferential water and solute flow using a scaling approach.

NEW YORK MAPPING GROUNDWATER CONTAMINATION POTENTIAL USING INTEGRATED SIMULATION MODELING AND GIS. R. J. Wagenet, R. B. Bryant, S. D. DeGloria, Cornell University, Ithaca, NY, and R. G. Perritt, USDA-SCS, Syracuse, NY. Report Period: 9/89-2/92.

Soil, climate, land-use and terrain data in a GIS were used to identify areas which may be a source of pesticide leaching. A computer model (LEACHM), using soil survey data, was used to evaluate leaching potential. Representative rainfall distributions were selected for each climate region using leaching indices for twenty years of data. Evaluations of the leaching hazards of atrazine, cyanazine and pendimethalin on corn in Connecticut, Rhode Island and New York are complete. The study has shown the relative importance of soil data, climatic data and assumptions regarding lower boundary conditions and organic matter distribution in the soil profile.

NEW YORK & CONNECTICUT PROTECTING GROUNDWATER FROM NITRATE ON DAIRY FARMS IN THE NORTHEAST. R. J. Wagenet, S. D. Klausner, and R. A. Milligan, Cornell University, S. R. Kaffka and V. R. Kanneganti, Sunny Valley Foundation, New Milford, CT. Rpt Period: 5/90 - 2/92. This study was initiated to investigate the benefits of incorporating orchardgrass into corn-alfalfa rotations for reducing manure-N loss to groundwater. Slurry and bedded manure at 150, 300 and 450 kg N ha⁻¹ yr⁻¹ were split applied one, two or four times for 2 years. Data were collected for

crop yield, N uptake, and soil and groundwater nitrate-N. It appears that orchardgrass may be used as an effective 'nitrogen sink crop' to absorb excess manure-N on dairy farms. The crop removed 423 kg N ha⁻¹ y⁻¹ in 11,400 kg of forage dry matter. No significant N losses were detected in deeper soil horizons or in the groundwater, even at 80 MT ha⁻¹ y⁻¹ of manure application (450 kg N).

NORTH CAROLINA PREFERENTIAL MOVEMENT OF WATER AND SOLUTES THROUGH SOIL/SAPROLITE SEQUENCES. A. Amoozegar, S. W. Buol, W. P. Robarge, M. J. Vepraskas, and R. M. Kretzschmar, North Carolina State University. Report Period: 7/91 - 2/92.

Two sites in the Piedmont region of North Carolina were evaluated for field and laboratory studies of solute and colloidal clay transport through macropores. Intact core samples, 6.6 cm diameter and 10 to 20 cm long, were collected from the Bt horizons and their underlying saprolite at each site. A large pit was constructed at one of the sites for profile description, excavation of large soil blocks, and collection of samples for chemical, physical, and mineralogical characterization of the soil/saprolite continuum. For studying movement of soil particles through soil and saprolite, clay colloids were separated from the Ap horizons of three different Ultisols and tested for their ability to coagulate in suspensions having different chemical compositions. The results indicated that humic substances may retard coagulation of clay colloids in a suspension.

NORTH CAROLINA & VIRGINIA REMOVAL OF NONPOINT SOURCE POLLUTION BY VEGETATED AND RIPARIAN BUFFERS. J. W. Gilliam, J. E. Parsons, R. B. Daniels, North Carolina State University, and T. A. Dillaha, Virginia Polytechnic and State Univ. Report Period: 7/91 - 2/92.

Three field experiments designed to evaluate sediment and pollutant movement from agricultural landscapes through both grass buffers and riparian areas are being monitored in North Carolina and Virginia. The two field sites in North Carolina, one in the Piedmont Region (near Raleigh, NC) and the other in the Coastal Plain region (near Kinston, NC) are instrumented. The third site is currently being installed in Ridge and Valley Region of Virginia. Each site enables comparisons of surface runoff from agricultural source areas filtered through 2 lengths of grass buffers (4.3 m and 8.5 m lengths) and riparian buffers (4.3 and 8.5 m lengths). Detailed storm hydrographs and surface water quality during each rainfall event are measured. Our initial storm data indicates that grass buffers can reduce sediment loading by more than 75% while reducing surface chemical loading by as much as 50%. Development has begun on a storm by storm model to study water-sediment-chemical flow through these buffers. Additional modeling work is also starting to evaluate the application of existing hydrologic/water quality models such as CREAMS to this problem.

NORTH CAROLINA GROUND WATER CONTAMINATION POTENTIAL USING MODELS, GIS, AND REMOTE SENSING. S. Khorram, R. L. Huffman, North Carolina State Univ. Rpt Per: 6/90 - 2/92. The major goals of this project are to integrate satellite imagery; digital maps of soils, topography, field boundaries, weather stations, and watersheds; and related multi-temporal tabular databases into a GIS that can be used with GLEAMS to predict pesticide leaching for individual agricultural fields and larger regions. To date the software, satellite imagery, base maps, coverages, and tabular databases required have been obtained. Digitizing and integration of the databases in Arc/Info are essentially complete. The building of a GIS to GLEAMS interface is well underway with several essential components completed. The results will (1) show how widely varying data types can be integrated into a vector based GIS, and (2) demonstrate how GLEAMS and other complex water-quality models can be used efficiently within a GIS framework for repetitive or large area analysis.

NORTH CAROLINA EFFECTS OF WATER TABLE MANAGEMENT ON GROUNDWATER QUALITY. R. W. Skaggs, J. W. Gilliam, T. J. Sheets, R. O. Evans, J. E. Parsons, C. L. Munster, North Carolina State University. Report Period: 6/90 - 2/92.

A 34 acre research site with subsurface drains was instrumented to measure surface and subsurface drainage and ground water quality. Field studies to document nutrient and pesticide fate were conducted under free drainage, controlled drainage and subirrigation conditions. The two-dimensional ground water flow and chemical transport model, VS2DT, was modified to include

subsurface drains and the transport of more than one chemical. The data from the field studies were used to test the simulations. Subsurface aldicarb losses were less from subirrigation and controlled drainage than from free drainage, but all losses were less than 0.02% of the amount applied.

OHIO SURFACE-SUBSURFACE WATER AND CHEMICAL MOVEMENT AND INTERACTIONS ON AGRICULTURAL WATERSHEDS. J. V. Bonta, W. M. Edwards, L. B. Owens, USDA-ARS, Coshocton, OH. Report Period: 1/90 - 2/92.

Urban's Knob (UK), located at the ARS Coshocton location, is an isolated 12-ac hilltop in which an impervious underclay outcrops along its periphery. Instrumentation efforts are continuing on UK to achieve the project objectives and to understand the subsurface flow system on the area. Twenty-five wells and 20 rain gages have been installed. Samples from wells, rainfall and runoff measurements, and field observations of water-level recovery in wells show the importance of quantifying spatial variability of natural characteristics. Knowledge of spatial variability is important for representative sampling of study areas, and for successful modeling and extrapolation of results. The very low baseline concentrations of simazine, cyanazine, alachlor, and atrazine found in UK ground water suggest that effects of the superimposed agricultural management practice in ground water will be directly attributed to the practice. Future investigations on UK will include studies of surface/ground-water interactions (quantity and quality), rainfall characterization, runoff generation, ground-water quality and hydraulic variability, and ground-water modeling in the fissured hilltop.

OHIO & INDIANA ROLE OF WATER TABLE POSITION AND HISTORY ON THE FATE OF SUBSURFACE CONTAMINANTS. L. C. Brown, S. J. Traina, The Ohio State University, R. F. Turco, Purdue University, and W. A. Dick, The Ohio State University. Report Period: 7/91 - 2/92.

Two laboratory components are soil column solute transport and chemical/microbiological characterization of soil profile. Third component is modification/evaluation of ADAPT/GLEAMS computer models to predict nutrient and pesticide transport. Nitrate, bromide, alachlor, atrazine, metribuzin will be studied on 4 soils (3 hydric) being sampled for columns (30x100cm) and profile characterization. Initial site/soils investigations are underway. Two column sets from associated NCRPIAP work will be used with two additional column sets, which will be collected with a new device for large-diameter, undisturbed cores. Solute transport work planned for later in 1992. Other work has focused on methods development, and soil sample preparation from 3 of 4 soils. Analytic protocol for measurement of dissolved pesticides by HPLC has been developed for batch adsorption experiments. Recently constructed and calibrated HPLC with prep-scale columns will be used to obtain breakthrough curves for pesticides. Preliminary microbiological work indicates that both atrazine sorption and total microbial biomass in surface soils (0-30 cm) is much greater than at any other depth to 100 cm.

OHIO WEED MANAGEMENT SYSTEMS TO REDUCE GROUNDWATER CONTAMINATION IN NO-TILL CORN. J. Cardina, W. A. Dick, and S. Kent Harrison, Ohio State University - Ohio Agricultural Research and Development Center. Report Period: 7/91 - 2/92.

Field studies were initiated to 1. measure herbicides in runoff and leachate water in no-till corn with three weed management systems and 2. measure weed control and crop productivity responses to alternative weed management systems. In the initial few months of this project field lysimeters were set up and calibrated and varying weed populations and cover crops were established. Data on herbicide movement, associated hydrology, and weed management will be collected beginning in 1992.

OHIO WATER TABLE MANAGEMENT FOR CROP PRODUCTION AND GROUND WATER QUALITY PROTECTION. N. R. Fausey and R. L. Cooper, USDA-ARS; A. D. Ward, T. J. Logan and J. G. Streeter, Ohio State University. Report Period: 1/90 - 2/92.

As planned, the Wooster site was managed as a corn/soybean rotation in 1990 and 1991. Soybean yields averaged 67 bu/ac and corn 196 bu/ac over the 2 years. The water table was maintained at approximately 12 inches below the soil surface from June 15 to September 15 each year and the high yield management system was used. Yields with drainage alone were 42 bu/ac for soybeans

and 123 bu/ac for corn using the high yield management system. Perched ground water and subsurface drainflow samples were obtained biweekly from May through September and once each month during the remainder of the year. The samples were analyzed for atrazine, alachlor, metolachlor, and nitrate. High levels of nitrate are observed in the shallow ground water beneath the subirrigated plots. Pesticides were seen at the top of the shallow ground water briefly after surface application. The construction of 12 new water table management plots at Hoytville was completed in late summer of 1991. Hydrologic tests of lateral and deep seepage were carried out in the Fall. Data collection will begin in these plots in 1992.

OHIO & MICHIGAN EFFECT OF SORPTION ON FATE OF PESTICIDES IN SUBSURFACE ENVIRONMENTS. S. J. Traina, G. K. Sims, T. J. Logan, Ohio State University and S. A. Boyd, Michigan State University. Report Period: 6/89 - 2/92.

We have studied the effects of sorption on the degradation of pyridine, by *Micrococcus luteus*, 2-methyl pyridine, by *Arthrobacter* and naphthalene by *Pseudomonas putida*, in suspensions of specimen clay minerals, and specimen clays coated with humic acid and alkylammonium surfactants. Additionally we have examined the affects of dissolved humic acid on pyridine degradation by *Micrococcus luteus*. In general, sorption to mineral and/or organo-mineral surfaces, and complexation by dissolved humic acid increased the time required for complete degradation of the parent compounds. The degradation rates of sorbed pyridine and 2-methyl pyridine were less than in pure solutions, but sorption appeared to increase the half-life of naphthalene by increasing the lagtime prior to the onset of degradation. Pyridine degradation at pH 5 was enhanced by sorption to smectite and 2-methyl pyridine degradation was greater in the presence of kaolinite than in clay free solutions.

OHIO ASSESSING AND MODELING WATER QUALITY BENEFITS OF WATER TABLE MANAGEMENT SYSTEMS. Andy Ward, Terry Logan, Scott Bair, The Ohio State University, Norm Fausey, USDA-ARS, Columbus. Report Period: 7/90 - 2/92.

Soil characterization and macropore research has been conducted at Wooster. A Plaster of Paris technique has been used in conjunction with ring infiltrometer tests. Bulk density, particle size analysis, and permeability testing has been conducted on soil cores. Excellent progress has been made with the ADAPT model. The model is an extension of GLEAMS which includes drainage, subirrigation, improved snowmelt and runoff algorithms, deep seepage, and macropore flow due to cracking. Data from an experiment at Castalia were used to validate the hydrologic components of the model. The pesticide transport capabilities of the model have been completed and tested with data from Wooster and Hoytville. The model gave reasonable predictions which are in acceptable agreement with the observed values. A statistical analysis of 3 years of water quality data for Wooster showed that metolachlor movement into the ground water is primarily a function of the proximity of the water table to the surface, precipitation within the first few weeks after application, and preferential flow.

OHIO THE OHIO BURIED VALLEY AQUIFER MANAGEMENT SYSTEMS EVALUATION AREA. Andy Ward, Scott Bair, Terry Logan, Sue Nokes, The Ohio State University, Norm Fausey, Steve Workman, USDA-ARS, Steve Hindall, Martha Jagucki, USGS. MSEA Project. Report Period: 4/90 - 2/92. The Ohio MSEA is part of a regional study to develop improved farming systems which reduce adverse impacts on water resources while maintaining productivity and profitability. Progress has been excellent with the following activities completed on schedule: the installation of the monitoring systems; site characterization activities; and the initiation of data collection and farming activities. More than 6,000 water, soil, and plant samples were obtained during the 1991 growing season and 25 specific research projects are in progress. Extensive documentation includes: 5 volumes describing the Ohio Project (project description, administration, two protocol documents, and a QA/QC document); a regional project document; and several brochures, newsletters, and extension fact sheets. Extensive regional coordination has been undertaken and project personnel have participated in many regional meetings, workshops, and professional society meetings. An External Advisory Board was appointed and has met on two occasions.

OKLAHOMA & FLORIDA AGRICULTURAL CHEMICAL IMPACT EVALUATION AND MANAGEMENT SYSTEM. D. L. Nofziger, C. T. Haan, Oklahoma State University, and A. G. Hornsby, University of Florida. Report Period: 7/89 - 7/91.

The objective of this project was to develop a computer-based system to estimate the risk of ground water contamination by pesticides. The system was developed by interfacing a chemical transport model, CMLS, to a geographical information system, creating a weather interface for the model, and building the required databases. The system was demonstrated to federal, state, and local agencies, presented at numerous national meetings including the Water Technology Board of the National Academy of Science, and used in training courses. The Oklahoma Department of Agriculture is adopting it. The system is being used to make watershed assessment in the Lake Manatee Water Quality Demonstration Project and the Karst Cropland HUA project in Florida, and in Lake Creek watershed and Tipton Water Quality projects in Oklahoma. This system will facilitate informed decision-making wherever it is used.

OKLAHOMA, FLORIDA & NORTH CAROLINA ECONOMICS OF MANAGING PESTICIDES TO REDUCE WATER QUALITY DEGRADATION. D. L. Nofziger, Oklahoma State University, A. G. Hornsby, University of Florida, Dana Hoag, North Carolina State University. Report Period: 7/91 - 2/92.

The purpose of this research is to develop a scientifically sound decision-support system to aid peanut farmers in selecting pesticides and managing production systems to minimize risk of degrading groundwater quality. The system incorporates economic as well as environmental considerations. Work to date has focused on development of data bases and knowledge bases required in the system and upon implementation and evaluation of a prototype system. A simplified prototype is operational for herbicide selection. Methods of reducing the time required for Monte Carlo simulations of chemical transport are also being evaluated. The basis of the system has been reviewed and accepted for publication in the Journal of Environmental Quality.

OKLAHOMA ECONOMIC IMPACTS OF GROUND WATER QUALITY MANAGEMENT. P. E. Norris, H. P. Mapp, D. L. Nofziger, C. T. Haan, Oklahoma State University. Report Period: 7/91 - 2/92.

Enterprise budgets have been developed for a representative peanut farm in Caddo County, Oklahoma. Preliminary runs of the CMLS physical transport simulation model indicate the potential for movement of some agricultural chemicals to ground water in the study area. Irrigation management practices are particularly important as indicators of chemical movement. However, the quantity of chemical leached, the time required for chemical movement, as well the distance moved by the chemical all vary widely depending upon soil type and weather patterns. This information will be used to determine the probability of chemicals reaching ground water under alternative agricultural management scenarios.

OKLAHOMA PREVENTION OF GROUND AND SURFACE WATER CONTAMINATION BY NEW AGRICULTURAL MANAGEMENT SYSTEMS. S. J. Smith, A. N. Sharpley, and J. W. Naney, USDA-ARS, Durant, OK. Report Period: 2/91 - 2/92.

Field, laboratory, and model simulation studies were conducted to assess the impact of animal waste management, use of cover crops, and fixed soil N on the potential movement of agricultural chemicals to surface and ground water in the Great Plains. The long-term application of poultry litter increased the surface soil total N and P content a respective 10- and 22-fold compared to untreated soils. Model simulations show that litter applications have the potential to enrich the nutrient content of runoff, emphasizing the need to carefully manage repeated applications to minimize potential runoff losses. Cover crops reduced soil, N, and P loss (60-90%) in runoff from several Southern Plains watersheds, although the bioavailable portion in soluble and particulate forms, may increase (20-40%). Accurate predictions of N and P transport in runoff from watersheds, with and without cover crops, were obtained using kinetic and enrichment ratio approaches. Preliminary results indicate the ammonium-fixing properties of illitic soils may be an important management factor.

OKLAHOMA & TEXAS WATER QUALITY IMPLICATIONS OF PLAYA LAKE CONTAINMENT OF FEEDLOT WASTES. S. J. Smith, A. N. Sharpley, and J. W. Naney, Durant, OK, and B. A. Stewart, Bushland, TX, all USDA-ARS. Report Period: 2/91 - 2/92.

In 1991, a playa that had been used for more than 20 years to contain beef cattle feedlot runoff was sampled at four locations to a depth of 17 m. In addition, a runoff retention pond constructed in 1974 on the more permeable side slope of a playa was sampled at 18 locations to depths ranging from 3 to 10 m. Less than 3 mcg/g $\text{NO}_3\text{-N}$ were found below 1 m in the playa samples. Ammonium-N concentrations in the top 2 m of the playa bottom ranged from about 20 to 125 mcg/g, and values of 5 to 10 mcg/g were sometimes found at depths beyond 10 m. Therefore, some limited percolation is suggested. In contrast to the playa bottom, the samples from the more aerobic area around the retention pond contained higher concentrations of NO_3 but lower amounts of NH_4 . The highest $\text{NO}_3\text{-N}$ concentrations were about 250 mcg/g below 3 m. Additional studies are needed, but these results indicate little evidence that N movement through playa bottoms is degrading the quality of the underground aquifer.

OREGON NONPOINT SOURCE POLLUTION AND AGRICULTURAL PRACTICES: SOURCE TERM, MIXING ZONE, AND THE STEADY STATE CONDITION. L. Boersma, R. Mason, Oregon State University. Report Period: 9/89 - 2/92.

The hypothesis being tested is that for a given farm management system concentrations of chemicals applied at the soil surface can never rise above a certain value--"the steady state" concentrations--in the groundwater because of the dynamic interactions between rate of application, vadose zone transport, and groundwater flow. This concept is not recognized in development of policy. Validation of the hypothesis requires determination of application--the source term--and hydrodynamic behavior in groundwater--the sink term. Survey of use of fertilizers and weed and pest control chemicals was completed as planned. One hundred and fifty farmers in two different climate zones participated by completing a diary on which they made daily entries of each activity as it occurred on the field selected for the survey. Responses have been entered on a computer data base and analysis is in progress. Mathematical models were developed for determination of the "steady state" concentration. Simulations show how concentrations are determined by spatial variability of the hydraulic conductivity field. Results emphasize uncertainty associated with point sampling in large aquifers.

OREGON DYNAMIC MODELING OF ALTERNATING-FURROW IRRIGATION TO MINIMIZE NITRATE LEACHING TO GROUNDWATER. A. R. Mitchell, C. C. Shock, G. M. Perry, Oregon State University. Report Period: 4/91 - 2/92.

The soil hydraulic properties were obtained for use in the model. Both the Eastern and Central Oregon soils' conductivity values were determined by the instantaneous drainage profile method. The van Genuchten equations for the soil water retention isotherm have been determined. A model, SWMS_2D, has been selected for 2-D solution of the water and solute flow problem in furrow irrigation. In order to validate the water flow model for furrow irrigation, a grid of soil sensors was developed for collecting soil moisture at one-minute intervals that will detect the progress of the wetting front. Granular Matrix Sensors (Watermark) were connected to a multiplexor and datalogger in a field furrow. The sensor response time was determined to be less than one minute. In 1992, alternate-furrow irrigation experiments will be conducted on a wheat field following onions and on peppermint.

OREGON FATE AND CYCLING OF ^{15}N -LABELLED DAIRY MANURE. D. D. Myrold, J. A. Moore, M. Gamroth, and J. E. Thies, Oregon State University. Report Period: 6/90 - 2/92.

^{15}N -labelling of dairy manure was accomplished as planned. Time course manure samples were fractionated to determine atom percent ^{15}N and N content of the $\text{NH}_3\text{-N}$, amino sugar-N, amino acid-N, and acid insoluble-N fractions. Kinetics of label incorporation into the different fractions was described. A poster detailing these results was presented at the American Society of Agronomy Annual Meeting in Denver, CO, October 1991. Manure with the higher and more homogeneous ^{15}N label has been applied at three rates (200 kg N ha⁻¹ yr⁻¹, 400 kg N ha⁻¹ yr⁻¹, and unamended) to PVC mesocosms at three field locations in Oregon beginning in three different seasons: spring (May 1991); fall (Nov 1991); and winter (Feb 1992). Mesocosms have been sampled every

three months following application of ^{15}N -labelled manure to determine plant uptake, gaseous N losses (NH_3 volatilization and denitrification), leaching losses, and transformation of N into various organic and inorganic N pools.

OREGON & NEW YORK DEVELOPMENT AND TESTING OF WICK LYSIMETERS FOR OBSERVATION OF SOLUTE TRANSPORT. J. S. Selker, J. Moore at Oregon State University, and T. S. Steenhuis, J.-Y. Parlange at Cornell University. Report Period: 6/91 - 3/92.

The primary goal of this project is the development and testing of passive capillary samplers (PCAPS) for monitoring water quality in soils. A central problem faced in the design and construction of PCAPS is control over the physical properties of the capillary wicks. We have identified and obtained wick samples from 12 producers, with 32 wick varieties presently under testing. Of particular interest are samples obtained from a producer (Amatex Corp.) who can consistently control the density of weave of the wick fabric which enhances our ability to match the capillary properties of particular soils to samplers. Structural components of two PCAPS sampler designs are being assembled for spring 1992 installation. These samplers incorporate new one-piece cast aluminum hard-anodized frameworks and molded fiberglass sampler bodies. Ongoing tests of the capillary properties of wicks show significant differences between wicks of similar appearance. These results are expected to lead to improvements in PCAPS sampler performance.

PENNSYLVANIA SOIL MANAGEMENT OF RESIDUAL MANURE NITROGEN AFFECTING NITRATES IN GROUND WATER WITHIN LIMESTONE TERRAIN IN LANCASTER COUNTY, PA. D. E. Baker, A. T. Phillips, J. P. Senft, C. S. Baker, Penn State University. Report Period: 7/90 - 2/92.

Dairy management programs over the past 30 years increased crop yields 150%. In the mid 80's it was found that the existing systems were causing nitrate-N pollution of ground water. Water pollution is associated with liquid manure storage systems which allowed for increased number of cows and a decrease in straw bedding. For these well aerated soils, it was found in 1991 that additions of wastes with a high C:N ratio applied with and without additional manure-N increased the microbial immobilization of excess N and prevented the leaching of excess nitrate-N to ground water. The conclusion is that many farms do not have an excess of N, but rather a deficient quantity of manure carbon.

PENNSYLVANIA USE OF MICROORGANISMS OR ENZYMES FOR DECONTAMINATION OF PESTICIDE-POLLUTED SOIL AND WATER. J.-M. Bollag, S.-Y. Liu, Penn State Univ. Rpt Per: 10/89 - 9/91.

In an effort to develop methods to detoxify pesticides, we studied the biotransformation of metolachlor. Various enrichment techniques were used to isolate metolachlor-transforming microorganisms. The most common transformation reactions observed with various bacteria and fungi were dechlorination, demethylation and hydroxylation of the side chains. In contrast to the results obtained with pure cultures, we demonstrated mineralization of metolachlor with soil samples. Our results suggest that while a single organism may not be able to completely biodegrade metolachlor, a microbial population is able to mineralize the herbicide. These findings may prove useful to an understanding of the mechanisms involved in the microbial degradation of pesticides and for developing methods of removing xenobiotics from contaminated soils and waters.

PENNSYLVANIA ESTIMATION OF ANION TRANSPORT IN SOILS USING ZERO-TENSION LYSIMETERS. R. H. Fox and D. D. Fritton. Pennsylvania State Univ. Report Period: 9/89 - 8/91.

The 3-yr average nitrate-N concentrations in leachate collected in zero-tension pan lysimeters at the economic optimum N fertilizer rate were 18.8 and 19.3 mg/L for non-manured and manured corn, respectively. The collection efficiency of the 18 lysimeters as estimated by Br⁻ recovery and water budget analyses ranged from 13 to 92% with an average of 54%. Using efficiency-corrected values, the amount of nitrate-N leached at the economic optimum N rate in the non-manured corn ranged from 80 to 133 kg/ha with an average of 107 kg/ha or 36% of the N applied. The leaching model LEACHM adequately predicted water flow, but was only moderately successful in predicting Br⁻ or nitrate leaching due to the model's inability to model solute movement in well-structured soils where macro-pore flow predominates.

PENNSYLVANIA NITRATE LEACHING IN CONTINUOUS CORN AND MANURED CORN-ALFALFA ROTATIONS. R. H. Fox, D. D. Fritton, W. P. Piekielek, J. D. Toth, Pennsylvania State University. Report Period: 10/91 - 2/92.

Nitrate leaching losses from N fertilized corn and from alfalfa are being measured with zero-tension lysimeters at a depth of 1.2 m beneath a field in a corn-alfalfa rotation. The 1991 growing season was very dry, with a growing season rainfall deficit 188 mm below the 30-year average. Eighty mm of irrigation water from a drip emitter system was applied to both crops. Despite irrigation, the drought apparently caused some yield loss in the alfalfa, with estimated total production 5.84 Mg ha⁻¹. The irrigation allowed maximum corn grain yields of 9.25 Mg ha⁻¹, which are similar to those normally observed at this site. The economic optimum N rate was 185 kg ha⁻¹. There was very little leachate collected, and most (84%) was collected below the corn. The flow-weighted mean NO₃-N concentrations in the corn leachate ranged from 2.11 mg L⁻¹ in the 0 kg ha⁻¹ fertilizer plots to 12.06 mg L⁻¹ in the 200 kg ha⁻¹ plots. Alfalfa leachate concentration averaged 3.70 mg L⁻¹.

PENNSYLVANIA MICROENCAPSULATION AND ADJUVANT EFFECTS ON HERBICIDE LEACHING AND PERSISTENCE. J. K. Hall, R. O. Mumma, N. L. Hartwig, L. D. Hoffman, Penn State University. Report Period: 5/90 - 2/92.

Greenhouse bioassays were completed on soil collected in late fall of 1990 and 1991 from the surface 5 and 15 cm of a rotation study involving two adjuvants applied with atrazine and metolachlor. Growth suppression of the test crop (oats) was evident for both adjuvant-amended herbicide treatments. Atrazine-induced tissue damage was most evident and oat yields were consistently lower at the recommended 1.7 kg/ha rate. In 1991, yields were lower on NT than CT-sampled soil (5 cm). Adjuvant-induced effects were not as defined for metolachlor as with atrazine. Chemical analyses of these soils is in progress; general analysis of bioassay results indicates that adjuvant-herbicide spray combinations have the potential of reducing herbicide losses by leaching in the field. In another bioassay, comparing microencapsulated and standard formulations of these herbicides, oat yield reductions were greatest on atrazine-treated soil sampled from the surface 5 cm, and, in general, yields were comparable between formulations.

PENNSYLVANIA KARST AQUIFER POLLUTION ASSAY BY VULNERABILITY INDEX DETERMINATIONS. D. A. Kurtz, R. R. Parizek, Pennsylvania State Univ. Rpt Per: 5/91 - 2/92. Assessment of the groundwater vulnerability falls generally into two research areas: field/geological and laboratory analysis. Field Progress: An operating field stilling well was installed and 24-hour recorder operations started to measure flows from Linden Hall aquifer. Measurement of spring flows was accomplished at numerous times to calibrate the stilling well readings. The same operation at the Rock Springs spring has been stalled for lack of permission of property owner. Numerous rainfall measuring stations have been established and recording forms completed. The process of gathering pesticide usage on individual farms was commenced to develop the techniques of obtaining potentially sensitive information from each farm usage. Analysis: a list of possible pesticide contaminants has been compiled. Sources include Pesticides in Groundwater: Background Document of 1986, Safe Drinking Water Priority List, and local usage. Extraction method and capillary chromatographic development has been started.

PENNSYLVANIA ENVIRONMENTAL TRACING OF CHEMICALS PATHWAYS IN CROPLAND WATERSHEDS. H. B. Pionke, USDA-ARS, University Park, PA. Report Period: 1/90 - 2/92. Chemical and ¹⁸O contents of rainfall, streamflow, soil and groundwater during 4 storms in the Mahantango Creek Watershed showed: Subsurface return flow to always dominate the storm hydrograph; storm flow to consistently be about 1/3 rainfall and 2/3 soil plus ground water; and Si, but not SO₄, C₁, NO₃ nor NH₄ to be an equivalent tracer to ¹⁸O. Although the ¹⁸O patterns in throughflow compared to soil matrix waters collected at 20 sites over a 5-storm period was inconclusive, specific storms at selected sites showed much of the quick flow captured at the one-meter depth to be rainfall, not displaced matrix water. Sampling all hydrologic components during storm events over several sites at one time or over several times at one site showed ¹⁸O to be most useful for tracing surface runoff, seep sources, and quick flow through soils, but least useful for separating soil matrix, shallow and deep groundwaters.

RHODE ISLAND ATTENUATION OF GROUNDWATER NITRATE IN RIPARIAN BUFFER ZONES. A. J. Gold, C. G. McKiel, University of Rhode Island, and P. M. Groffman, Institute of Ecosystem Studies. Report Period: 5/91 - 2/92.

While riparian zones dominated by wet soils have been shown to attenuate groundwater nitrate (NO_3^-), more well-drained soils may be much less effective. Information is needed on the specific soil types that have high NO_3^- removal capacity. We are adding solutions enriched with NO_3^- and bromide to groundwater beneath different soil types within a riparian zone during both growing and dormant seasons. Measurements of plant roots and microbial processes are being made to determine what processes are contributing to observed NO_3^- attenuation. Work during this period has focused on experimental site layout and collection of preliminary data. We have found differences in groundwater oxygen levels and microbial activity within the site which should lead to major differences in NO_3^- attenuation.

SOUTH CAROLINA & NORTH CAROLINA TERRAIN CONDUCTIVITY TO QUANTIFY IMPACT OF FARM LAGOONS UPON GROUNDWATER QUALITY. D. E. Brune, Clemson University, P. W. Westerman, North Carolina State University. Report Period: 9/89 - 8/91.

A computer model has been developed which is capable of predicting averaged groundwater ionic strength and anion concentration in soils affected by animal waste lagoon seepage, using surface electromagnetic terrain conductivity as the primary sensing technique. This capability has significantly improved the ability of researchers and soil conservation engineers to assess and predict the impact of animal waste lagoons on groundwater water. Specific accomplishments have included; 1. development of a relationship between soil pore water conductivity and ionic strength and ion composition as affected by lagoon seepage, 2. development of a model of bulk soil conductivity under varying soil texture and pore water conductivity conditions, 3. a sensitivity study which defines the degree of importance of geohydrological conditions and lagoon seepage upon terrain conductivity (based on above models) and compares the predicted response to actual measured terrain conductivity, 4. the effects of the establishment of new lagoons upon groundwater and resulting terrain conductivity.

SOUTH CAROLINA IMPROVED IRRIGATION AND NITROGEN MANAGEMENT OF COTTON IN THE EASTERN COASTAL PLAIN. P. G. Hunt, C. R. Camp, and P. J. Bauer, USDA-ARS, Florence, SC. Report Period: 2/91 - 2/92.

Improved irrigation and fertilizer N management systems for cotton in the Eastern Coastal Plain of the United States will decrease the potential of groundwater contamination by nitrates. A 4-year study of buried microirrigation and N management on plant and soil N status as well as cotton yield was begun in 1991. Water management treatments were buried microirrigation tubing (two spacings) and rainfall only. Preplanting N application was 22 kg/ha; post-emergence nitrogen was added via the irrigation system in one application (90 kg/ha), in five weekly applications of 22 kg/ha, and 22 kg/ha when the GOSSYM/COMAX (GC) model predicted N deficiency (67 kg/ha was applied). No differences in lint yield were found among the N management treatments with irrigation. In the rainfall-only plots, the GC treatment produced 1705 kg/ha lint cotton (3.5 bales); 339 kg/ha more lint than the single N application with 45 kg/ha less N fertilizer. Nitrate movement in the soil and plant will be studied using depleted ^{15}N applied to one row in each plot.

SOUTH CAROLINA WATER QUALITY EVALUATION FOR DUPLIN COUNTY DEMONSTRATION PROJECT. P. G. Hunt, K. C. Stone, USDA-ARS, Florence, SC. Report Period: 9/90 - 2/92.

Agricultural practices on the watershed are typical for the Southeastern coastal plain and include row crop, poultry, swine, and cattle production. Stream water samples have been taken at hourly intervals and analyzed on 8 hour composites since installation (September 1990) at three sites on the watershed. Nitrate, ammonia, and orthophosphorus averaged 1.3, 0.07, and 0.1 mg/L at the background site; 5.7, 1.2, and 0.8 mg/L downstream of the intensive animal production site; and 2.3, 0.2, and 0.5 mg/L at the watershed outlet. This shows distinct contamination and the potential of improved water quality from BMP implementation on the contaminated tributary. Ground water samples taken from fields with row crops have had nitrate concentration around 8 mg/L. High nitrate levels (significantly exceeding 10 mg/L) were observed in ground water monitoring wells

on an undersized swine spray application field. We have worked with extension, SCS, and the landowner to implement improved management of this operation through enlargement of the spray field and through other available options.

SOUTH CAROLINA & KENTUCKY GROUNDWATER QUALITY AS AFFECTED BY PREFERENTIAL FLOW IN STRUCTURED SOILS. V. L. Quisenberry and B. R. Smith, Clemson University and R. E. Phillips, University of Kentucky. Report Period: 10/89 - 2/92.

Experiments were conducted in two important and extensive soils: Cecil sandy loam in SC and Maury silt loam in KY. The research has shown for structured soils that 1) significant amounts of chemicals can move through the soil by macropore flow, 2) less than 20% of the total soil volume maybe involved in the flow process, and 3) macropore flow occurs in the same pores for similar rainfall events. Flow through the subsurface horizons of each is quite similar, but less direct bypass flow occurs in the surface horizon of sandy loam soil. The data show that macropore flow can be directly related to soil physical characteristics, especially structure and texture.

SOUTH CAROLINA, KENTUCKY & ARKANSAS SOIL CLASSIFICATION SYSTEM FOR SOUTHERN REGION BASED ON WATER AND CHEMICAL TRANSPORT. V. L. Quisenberry, Clemson University, R. E. Phillips, Univ of Kentucky, and H. D. Scott, Univ of Arkansas. Report Period: 7/91 - 2/92.

We are developing a soil classification system based on water and chemical transport. We have grouped soils with similar physical (especially structure and texture) and chemical properties. Soils within a group will have some variability, but a given group will transport water and solute quite differently than another group. We are now in the process of validating our tentative classification system. Experiments conducted on soils in Kentucky and South Carolina support the classification system concept and suggest that management practices can be developed to reduce potential groundwater problems.

SOUTH DAKOTA, MINNESOTA & COLORADO TILLAGE INDUCED MICRORELIEF IMPACT ON NO₃ AND ATRAZINE MOVEMENT IN SOILS. D. E. Clay, T. E. Schumacher, S. A. Clay, and J. A. Bischoff, South Dakota State University; G. L. Malzer, University of Minnesota; M. J. Shaffer, USDA-ARS, Fort Collins. Report Period: 4/91 - 2/92.

The research activities have been completed as planned. During 1991, several objectives have been achieved. These include: (i) the initiation of field plots; (ii) installation of lysimeters, TDR, thermocouples, and neutron access tubes in microplots; (iii) obtaining and the analysis of background soil samples for inorganic N and atrazine and alachlor concentrations; and (iv) presentation of research finding at South Dakota Soil Moisture Clinic and Brooking Farm field tours. Preparations are underway for the 1992 growing season, and research activities between the two sites are coordinated.

SOUTH DAKOTA DEVELOP TECHNOLOGIES FOR MANAGING CORN ROOTWORM POPULATIONS WITH REDUCED INSECTICIDE INPUTS. G. R. Sutter, W. D. Woodson, M. M. Ellsberry, L. S. Hesler, Brookings, SD, USDA-ARS. Report Period: 4/90 - 2/92.

A large-scale management program (16 square miles) for corn rootworms was successfully conducted in 1991. Over 3000 acres of maize were treated with a semiochemical-based bait that used 98% less toxin than typically applied for management of these pests. The baits did not appear to adversely affect beneficial insects. Newly developed traps were employed to identify fields harboring pest densities above thresholds and of equal importance, identified fields that did not require treatment. Significant progress was made in development of decision support systems for IPM in maize production which will allow growers to use selected inputs for conducting environmentally sound management practices that are also economically feasible. Improved environmental quality will only be realized when the program has been in effect for consecutive years.

TENNESSEE & LOUISIANA THE EFFECTS OF TILLAGE ON FATE AND TRANSPORT OF PESTICIDES THROUGH UNSATURATED SOIL PROFILES. M. E. Essington, G. V. Wilson, and D. D. Tyler, University of Tennessee, and H. M. Selim, Louisiana State University. Report Period: 7/91 - 2/92.

The objectives of this research are to 1) quantitatively describe the association of fluometuron, metolachlor, and pendimethalin with dissolved organic carbon (DOC) extracted from long-term no-tillage (NT) and conventional tillage (CT) soils, 2) examine the influence of DOC on the sorption, sorption kinetics, and desorption of pesticides by NT and CT soils, 3) quantify the effect of tillage practice on the unsaturated transport of the herbicides, and 4) develop capabilities to mathematical model the unsaturated transport of the herbicides. Laboratory experiments have been initiated to characterize the aqueous association of the herbicides with DOC. Four methodologies are being assessed for their ability to quantify herbicide KDOC values: equilibrium dialysis, water solubility enhancement, gel filtration, and reverse-phase separation.

TENNESSEE & KENTUCKY EFFECTS OF TILLAGE AND CROPPING SYSTEMS ON TRANSPORT OF NITRATE THROUGH HETEROGENEOUS SOILS. G. V. Wilson, D. D. Tyler, J. Logan, University of Tennessee, and G. W. Thomas, R. L. Blevins, Univ of Kentucky. Report Period: 5/90 - 2/92.

In Tennessee, 81% of leachate samples had NO₃-N concentrations below the 10 mg/L MCL. Samples exceeding the MCL occurred during the growing season shortly after fertilization when flow out of the root zone was generally small. When large rainstorms occurred immediately following application as much as 50 kg/ha of NO₃-N was leached. Flow was greatest during the winter and spring when concentrations were below the MCL. In Tennessee, no-tillage appeared to reduce nitrate leaching under cotton and soybean systems. In Kentucky, losses of NO₃-N with no-tillage were considerably higher than with conventional tillage under soybeans and lower under corn.

TEXAS PESTICIDE DEGRADATION BY A GENETICALLY ENGINEERED FUNGUS. C. M. Kennerley, A. Garcia III, Texas A&M University. Report Period: 9/91 - 2/92.

Approximately one hundred transformants of the fungus *Gliocladium virens* containing the bacterial gene (*opd*) encoding for the enzyme, organophosphate hydrolase (OPH) were analyzed for their ability to produce the enzyme over a four week period. Western blotting of concentrated culture filtrate using polyclonal antibodies raised against OPH as probes revealed a weak signal. A fungal plasmid that can serve as a stable foundation for cassette exchanges to facilitate introduction of fungal promoters and other genetic elements has been constructed. A model that describes the amount and extent of fungal growth in a solid matrix is being tested. Hyphal mass is estimated by an image processing technique using algorithms designed to calculate the amount of hyphae in soil as hyphal lengths/cm.

TEXAS HYDRAULIC CONDUCTIVITY AND MACROPORE FLOW IN RELATION TO SOIL STRUCTURE. K. J. McInnes, L. P. Wilding, C. T. Hallmark, Texas A&M University. Report Period: 6/90 - 2/92.

Hydraulic information has been collected from 6 of the 18 soils targeted in this project. Hydraulic conductivity measurements have been made within distinct structural horizons of six soils in the Claypan land resource area of southeast Texas. Over all six soils and horizons, macropore flow, estimated from the difference in flow above and below 0.03 m tension, accounted for 70-80% of the saturated water flux. Large temporal variations in hydraulic conductivities existed in the surface horizons of soils with high shrink/swell characteristics. Hydraulic conductivities for a given soil decreased with depth for most horizons measured. Correlation of results with soil structure/macroporosity morphological properties has been initiated. The information being gathered will allow quantitative measurement of hydrological behavior to be related to data on soil resources that are available through the National Cooperative Soil Survey Program and, thus, provide critical information for evaluation of soil resources relative to nonpoint and point source groundwater pollution.

TEXAS DEVELOP COMPREHENSIVE WATER QUALITY MANAGEMENT MODELS. J. R. Williams and C. W. Richardson, USDA-ARS, Temple, TX. Report Period: 2/91 - 2/92.

A rainfall energy term was added to the SCS curve number based runoff models of EPIC and SWRRB to improve accuracy. A manure land disposal management component was developed for EPIC. In response to the SCS SWRRB Evaluation report, we have assembled a sediment yield data set consisting of 3,695 storms on 63 watersheds. We used these data to evaluate MUSLE and two versions of a four-parameter equation. The small watershed version (areas \leq 71.2 ha) of the

four-parameter model predicted sediment yields slightly better than the other two equations. We also assembled a large peak runoff rate data set from 170 watersheds throughout the U.S. Tests with these data indicate that the SWRRB peak rate simulator is superior to TR-55 in tracking seasonal variability. We plan to include the new sediment yield equations and TR-55 as options to MUSLE and the SWRRB peak rate simulator.

TEXAS, GEORGIA & FLORIDA MANAGEMENT OF DAIRY WASTE TO MINIMIZE POTENTIAL GROUNDWATER CONTAMINATION. M. L. Wolfe, M. A. Sanderson, K. J. McInnes, Texas A&M Univ, and M. Cabrera, Univ of Georgia, A. R. Overman, Univ of Florida. Report Period: 7/91 - 2/92.

One hundred forty-four 0.3 m diameter PVC tubes (microplots) were pressed into a 0.5 ha plot of "Coastal" bermudagrass. Non-labeled and ¹⁵N-labeled dairy waste will be applied to the microplots in early spring 1992. Forage and soil samples from plots of 'Coastal' bermudagrass established in 1990 and 1991 are being analyzed for nutrient concentrations. The plots received four rates (lb N/ac) of solid manure or liquid effluent. Winter wheat and tall fescue were interseeded into selected plots. Forage yields indicated no response to manure application, probably due to high levels of residual soil N. Simulation models which relate dry matter production and N concentration of forage grasses to applied N, harvest interval, and water availability, were shown to be applicable to two sets of data from Texas. Two manuscripts were submitted for publication. The LEACHM model is being evaluated for simulating the water and nitrogen balances related to the land application of dairy wastes.

UTAH OPTIMIZING IRRIGATION MANAGEMENT FOR POLLUTION CONTROL AND SUSTAINABLE CROP YIELDS. L. M. Dudley, R. J. Hanks, R. C. Peralta, Utah State Univ. Report Period: 9/89 - 2/92.

A simulation model and an optimization model have been created and validated. Simulation model salt profiles were compared with those observed in a fifteen year study of irrigation with saline water. The optimization model is calibrated with the simulation model results. The optimization model computes irrigation schedules and water applications that maximize the amount of available water and limit the flux of salt from the bottom of the root zone to specified values. The simulation model has been used to investigate the effects irrigating with minimum leaching on crop yield and root zone salinization. It has been found that leaching can be postponed for a number of years. This could result in significant water savings and a reduction in pollution.

UTAH ECONOMIC INCENTIVES FOR MANAGING NON-POINT PESTICIDE POLLUTION OF GROUNDWATER: A PROTOTYPE APPLICATION. T. F. Glover, R. C. Peralta, H. H. Fullerton, Utah State University. Report Period: 9/90 - 2/92.

A one-dimensional (vertical unsaturated flow) crop production/contaminant management model has been used to demonstrate that contamination of groundwater in the Davis-Weber area can be partially controlled by water table management through increased pumping but wells used for farm production purposes decrease in discharge. A regional groundwater planning model has been used to demonstrate that optimal steady state groundwater extraction rates in the same region can increase to over 150% of current rates but again discharge from wells used for irrigation decrease in prime agricultural areas of the region. Controls such as contamination taxes and water taxes are projected to cause significant changes in cropping patterns and reductions in land being irrigated in the region. Uniform policy imposition does not achieve private economic efficiency or a social optimum.

VERMONT EFFECTS OF CORN MANAGEMENT SYSTEMS ON NITRATE LEACHING POTENTIAL. F. R. Magdoff, W. E. Jokela, R. P. Durieux, H. R. Brown, Univ of Vermont. Rpt Period: 8/89 - 12/91.

The N management systems study was continued at the Fay Farm (silt loam soil). There were no yield differences between plots fertilized according to the routine recommendation system (RRS) and the Pre-sidedress Nitrate Test (PSNT). However, end of season (residual) soil NO₃-N to 1.2 m was 54 and 92 kg/ha less in the PSNT with and without manure system respectively than in the RRS. This is the second year that use of the PSNT resulted in lower NO₃-N leaching potential than use of the RRS. Groundwater NO₃-N has gradually declined during the experiment, but also

fluctuates with groundwater level. This experiment will continue through 1994 under CSRS Water Quality Project "NITROGEN MANAGEMENT SYSTEMS FOR CORN TO REDUCE NITRATE LEACHING."

VERMONT & NEW YORK NITROGEN MANAGEMENT SYSTEMS FOR CORN TO REDUCE NITRATE LEACHING. F. R. Magdoff, W. E. Jokela, R. P. Durieux, University of Vermont, H. Van Es, S. D. Klausner, L. D. Geohring, Cornell University. Report Period: 5/91 - 2/92.

Experiments were initiated on a clay and on a sand in Vermont. Soil matric potential, weather and soil nitrate levels were monitored during the growing season. Treatments were: a) Check; b) fertilizer N applied according to the Pre-sidedress Nitrate Test (PSNT); c) same as (b) but plots also received manure. Residual nitrates for treatments (b) and (c) to 1.2 m were about 60 kg/ha on the clay soil (check $\text{NO}_3\text{-N}$ is 46 kg/ha) and about 28 kg/ha on the sand (check $\text{NO}_3\text{-N}$ is 13 kg/ha). On the sand the PSNT with manure treatment yielded higher than PSNT without manure, but not on the clay. Sites have been selected in New York and instrumentation installed for continuous monitoring of NO_3 leaching in 1992.

VIRGINIA SOIL MINERAL NITROGEN AS A PREDICTOR OF NITROGEN FERTILIZER NEED OF WINTER WHEAT. M. M. Alley, P. C. Scharf, Virginia Polytechnic Institute and State University. Report Period: 7/90 - 2/92.

The first year of field experiments has been completed and the data analyzed; the second year of field experiments is underway. Results from the first year indicate that soil mineral nitrogen (N) measurements probably will not be useful for predicting optimum N rate at the first spring application, but tiller (shoot) density measurements appear very promising for making this prediction. A tissue-test system based on previous research is in place for making field-specific N rate recommendations at the second spring application. Making two spring N applications reduces nitrate leaching potential relative to the traditional single spring application, but for growers unwilling to make two applications, nitrate-N to 90 cm depth in January appears promising as a predictor of optimum N rate for a single application. These three tests combine to form a powerful and flexible integrated N rate recommendation system for winter wheat in the mid-Atlantic region. This system has the potential to be widely used by growers and to reduce nitrate leaching to groundwater by eliminating unnecessary or excessive N fertilizer applications. The second year's results will be used to evaluate and modify the two new components of the system; if favorable, technology transfer will begin.

VIRGINIA COMPOSTING AS A MEANS TO DISPOSE OF PESTICIDE WASTE. D. F. Berry, D. E. Mullins, G. H. Hetzel, R. W. Young, Virginia Polytechnic Institute and State University. Report Period: 7/90 - 2/92.

Composting, or solid state fermentation (SSF), was evaluated as a means to dispose of formulated pesticide waste. In sphagnum peat moss-filled bioreactors (constructed from 38-liter Rubbermaid waste containers) containing atrazine (herbicide) at loading rates of 1.4, 2.0, and 7.23 g kg^{-1} (dry weight basis), solvent extractable atrazine decreased to an undetectable level (day 104 of incubation), 95% (day 260), and 98% (day 245) of starting levels. Extractable carbofuran (insecticide) in peat-filled bioreactors with loading rates of 0.7, 1.8, and 5.0 g kg^{-1} decreased to undetectable levels within 100 days. Degradation of a prolonged lag period was observed for atrazine degradation at the highest loading rate. Disposal of formulated pesticide waste using SSF techniques represents a viable alternative to other available more expensive and technically sophisticated methods.

WASHINGTON DEVELOPMENT OF A SPATIAL DECISION SYSTEM FOR FARM MANAGEMENT OF NITROGEN FERTILIZER APPLICATIONS. D. J. Mulla and G. S. Campbell, Washington State University. Report Period: 8/89 - 7/91.

Applying variable rates of fertilizer is an alternative to the conventional practice of applying uniform rates. Research was conducted on a 57 ha irrigated farm in central Washington state to develop techniques for producing management maps for variable rates of nitrogen fertilizer. Soil properties, crop growth patterns, irrigation applications, and movement of a bromide tracer were monitored during the study. Variability in leaching was found to be closely related to spatial

patterns in soil texture and irrigation depth. Techniques involving geostatistics, geographic information systems, and joint frequency distributions were used to develop management maps of leaching potential. These maps could be used to determine how to fertilize each management zone within the field with an appropriate rate or blend of nitrogen fertilizer.

WASHINGTON & OREGON ON-FARM MANAGEMENT OF GROUNDWATER NITRATE POLLUTION IN PACIFIC NORTHWEST IRRIGATED AGRICULTURE. N. K. Whittlesey, D. Mulla, M. Frasier, Washington State Univ, R. Adams, G. Perry, M. English, Oregon State Univ. (Three awards). Report Period: 7/89 - 2/92.

Biophysical crop models have been validated for local conditions and modified to control irrigation uniformity. Optimization models linked to the crop models are used to evaluate managerial and policy options for abatement of nitrate pollution in groundwater from irrigated agriculture. Results indicate that up to 40% of current nitrate emissions to groundwater could be eliminated through improved irrigation and fertilization management with minimal loss of net farm income. Additional increments of abatement become increasingly more expensive. Policies affecting farmer use of water and fertilizer are most effective in achieving desired levels of emission control.

WEST VIRGINIA NEMATICIDE MOBILITY AND BIODEGRADATION: EFFECTS OF ORCHARD SOIL MANAGEMENT. J. Kotcon, A. Sexstone, West Virginia University, D. Glenn, USDA, Kearneysville, WV. Report Period: 5/90 - 3/92.

This project evaluates the influence of three orchard floor management systems, clean cultivated, herbicide treated, and killed sod, on the mobility and biodegradation of the nematicides carbofuran and fenamiphos. Degradation of fenamiphos was faster in herbicide treated than in killed sod and was faster than for carbofuran. Three enrichment cycles increased degradation of carbofuran ≥ 5 -fold. A methylcarbamate hydrolase (*mcd*) gene probe is being used to determine diversity of carbofuran-degrading microbial populations. Total bacterial DNA extracts from untreated soil hybridized with the *mcd* gene probe as did DNA from carbaryl-degrading bacteria; however other carbofuran-degraders did not.

WEST VIRGINIA WATER QUALITY IMPACTS OF AGRICULTURE IN SOUTHEAST WEST VIRGINIA. G. C. Pasquarell, D. G. Boyer, D. P. Bligh, USDA-ARS, Beckley, WV. Report Period: 7/90 - 2/92.

Preliminary results demonstrate the acute sensitivity of Karst conduit ground water to animal grazing practices. A direct relationship has been demonstrated between conduit water nitrates and percent agricultural land use. Strong seasonal trends in atrazine concentrations correlate with the period of basin-wide application. Fecal bacterial levels, however, do not appear to correlate primarily with agricultural activity. The following tasks remain: 1. Determine contaminant variations during high runoff, 2. Complete sampling within cave streams, 3. Establish field sites for study of sinkhole contaminant transport. Results should lead to new management practices for Karst terrain.

WEST VIRGINIA BACTERIAL QUALITY OF POINT-OF-USE FILTERS USED FOR TREATMENT OF RURAL GROUNDWATER SUPPLIES. J. W. Snyder, C. N. Mains, R. E. Anderson, and G. K. Bissonnette, West Virginia University. Report Period: 8/89 - 8/91.

Water quality was monitored for 24 rural, domestic groundwater supplies treated with point-of-use (POU), powdered activated carbon (PAC) filters. Heterotrophic plate count (HPC) densities were generally elevated by 0.86 and 0.20 logs of magnitude, respectively, for spring and drilled well water systems in PAC-treated effluents following an overnight stagnation period as compared with HPC in untreated influents. HPC densities in PAC-treated effluents could be significantly reduced below influent levels, however, after flushing the POU device for two minutes. PAC treatment significantly reduced the number of coliforms in product waters. Aside from periods of nonusage, such as overnight, PAC treatment did not appear to compromise the microbiological quality of private drinking water supplies.

WISCONSIN SAFE ON-FARM DISPOSAL OF DILUTE PESTICIDE WASTES. G. Chesters, J. M. Harkin, M. A. Anderson, H. W. Read, M. A. Aguado, C.-P. Chen, University of Wisconsin-Madison. Report Period: 7/90 - 2/92.

Surveys identified the most widely used pesticides in Wisconsin. Some rinsates are used as make-up water but disposal of mixtures containing incompatible pesticides is still problematic. Sintered TiO₂ was used to destroy pesticide residues by photocatalysis in two bench-scale reactors with glass flow-through cells coated with TiO₂ films and one with a packed bed of porous TiO₂ pellets. Increasing light intensity raises degradation rates of formic acid used as a standard but lowers energy efficiency. Atrazine disappeared from irradiated solutions at 1.4 ppm/hr. Chemical treatments of mixed pesticide wastes were compared with photocatalysis: Pesticide detoxification by dechlorination through hydrolysis, assessed by Cl⁻ production, showed that fly ash works but not ag lime. Degradation studies using ultraviolet-irradiated H₂O₂ are proving more effective. Economic feasibility of the various techniques is being studied.

WISCONSIN & NEW YORK USING GROUND PENETRATING RADAR TO IMPROVE MONITORING AND PREDICTING PREFERENTIAL SOLUTE MOVEMENT IN SANDY SOILS. K.-J. S. Kung, University of Wisconsin-Madison; T. S. Steenhuis, J.-Y. Parlange, Cornell Univ. Report Period: 6/90 - 2/92.

Preferential flow initiated by the funneling mechanism in sandy unsaturated soil is unambiguously demonstrated. The capability of GPR technology to nondestructively "see through" a soil profile and obtain accurate information on the layering structure in sandy soil is also demonstrated. A finite element solute transport model suitable for predicting transport in layered sandy soil was developed and validated. A technique to reconstruct the 3-D soil layer structure from 2-D GPR images was developed. Results have reached scientists and the general public through presentations and publications. We are currently focusing on how to filter out noises and false images from raw GPR data by 3-D migration and deconvolution.

WISCONSIN MOVEMENT OF ATRAZINE AND ALACHLOR THROUGH THE UNSATURATED ZONE: MODEL CALIBRATION AND VALIDATION. K. Mc Sweeney and B. Lowery, University of Wisconsin-Madison. Report Period: 6/89 - 2/92.

The study was designed to explain differences in apparent rate and amount of movement of herbicides (atrazine and alachlor) through two broadly similar soils in irrigated portions of the Lower Wisconsin River Valley (LWRV) and Central Sands Area (CS), and encompasses field and laboratory experiments and simulation modeling. Field work, which includes evaluation of management practices to reduce herbicide transport, has been concentrated in the LWRV because groundwater is much faster in the LWRV soil than in the CS soil. Rapid water movement coupled with a lower intrinsic potential of the soil constituents to bind and degrade contaminants help to explain the larger ground-water contamination susceptibility associated with LWRV soils. Findings are being used to refine simulation models for extrapolation and information dissemination.

WISCONSIN PREFERENTIAL MOVEMENT OF WATER AND AGCHEMICALS IN SANDY SOIL WITH ANIMAL BURROWS. J. M. Norman, K. McSweeney, B. Lowery, University of Wisconsin. Report Period: 7/91 - 1/92.

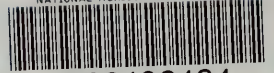
Weekly measurements of the number of ant burrows and leaf area index were made during the 1991 growing season on 66 plots in a corn field (under different irrigation, tillage and nitrogen treatments) located near Arena, WI. Soil pH, organic matter, phosphorous and potassium content, total dry matter and yield were measured for the 66 plots at the end of the season. Tension infiltrometers were used to measure infiltration rate in areas with and without ant burrows. Preliminary results indicate that (1) ant burrow abundance tends to be reduced by irrigation, conventional tillage and reduced nitrogen application, and to be increased by high phosphorous and potassium content and pH about 6.0 (2) infiltration rate increased by 33.5% at zero tension when an ant burrow is present and the water flows into individual burrow openings at rates ranging from 1.5 to 7.3 cm³/sec depending on the size of the burrow (3) six excavated ant burrows varied in depth from 20 cm to 75 cm. Laboratory experiments are initiated on soil columns to study water and chemical movement in the presence of ant burrows.

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1992

**WATER QUALITY RESEARCH--THE PRESIDENT'S INITIATIVE
PROGRAM REVIEW AND EVALUATION
1992**

PRIORITY COMPONENTS

COMPREHENSIVE REPORT

WEST REGION

**Agricultural Research Service
Cooperative State Research Service
U.S. Department of Agriculture**

**in Cooperation
with**

**State Agricultural Experiment Stations
and other Collaborators**

**at
Tucson, Arizona**

**United States
Department of
Agriculture**



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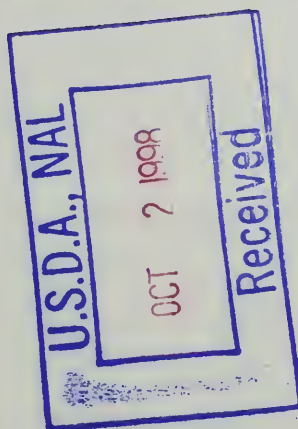
ACKNOWLEDGEMENT

Many people contributed to the success of the 1992 evaluation and review of the water quality research program supported largely by FY 1990 and 1991 funds from the President's Initiative on Water Quality, awarded through the Agricultural Research Service (ARS) and Cooperative State Research Service (CSRS) of the U.S. Department of Agriculture.

Baton Rouge, Louisiana and Tucson, Arizona were selected as sites for the southern and western regions, respectively. Planning was largely through efforts of administrators and scientists of the State agricultural experiment stations (SAES), ARS and CSRS. We appreciated guidance from SAES administrative advisors for water quality V. V. Volk, Oregon and J. M. Davidson, Florida. Significant assistance was provided by C. B. Rumburg, J. M. Horton, and B. L. Schmidt of CSRS, D. A. Bucks, ARS, H. Mattraw, U.S. Geological Survey, and others. In addition to the above, effectiveness of the meetings was enhanced through participation by representatives of the Extension Service, Soil Conservation Service, Economic Research Service and the fertilizer and chemical industries.

Members of the Evaluation Panels for the two meetings are the following. They are also listed as Work Shop Participants at the end of each Research Problem Area (RPA) work group report.

D. E. Albrecht
Texas A&M University
L. L. Boersma
Oregon State University
B. G. Ellis
Michigan State University
W. C. Koskinen
ARS-USDA, St. Paul, MN
R. Lal
Ohio State University
K. L. Wells
University of Kentucky



H.H. Cheng
University of Minnesota
C. T. Haan
Oklahoma State University
J. F. Power
ARS-USDA, Lincoln, NE
R. S. Rauschkolb
University of Arizona
H. D. Scott
University of Arkansas
R. J. Suppalla
University of Nebraska

Appreciation is extended to these panelists for many hours of study and evaluation of the large number of abstracts and progress reports prepared by the researchers. Their analysis reports at the beginning of the meetings were a stimulus for discussions that followed in the respective RPA Work Groups. Their final reports, contained herein, show many important accomplishments of this young research program. And, the recommendations from the work groups provided guidance for emphasis in the forthcoming request for proposals of research for the fiscal year 1993 competition.

A special thanks is extended to the hosts and local organizers, whose efforts were largely responsible for efficiency of program operations and a very warm welcome. Some of those for Baton Rouge were H. R. Caffey, Chancellor, Louisiana State University (LSU) Agricultural Center and K. W. Tipton, Vice Chancellor/Director, and arrangements organizers H. M. Selim, LSU, and J. L. Fouss and G. H. Willis, ARS. University of Arizona (UA) hosts were E. G. Sander, Dean and P. J. Wierenga, Soil and Water Science-Head, arrangements organizer was A. W. Warrick, UA, with assistance by L. J. Lane, ARS and others.

The evaluation and review process and the Comprehensive Reports and Summary were coordinated and edited by C. M. Smith, Visiting Professor, Pennsylvania State University.



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FOREWORD

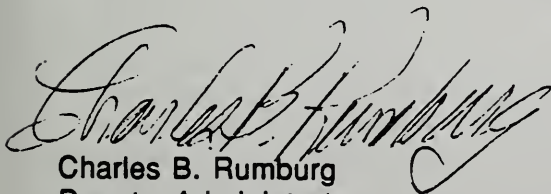
The use of pesticides, fertilizers, manures and wastes contributes substantially to the productivity and efficiency of agriculture and to the well-being of rural and urban communities. There are concerns, however, about contaminant risk to human health, water quality, and an ecologically stable environment. The President's Initiative on Water Quality was initiated in 1990 to provide new and expanded emphasis on the protection and enhancement of our water resources.

This action provided major impetus to the USDA Water Quality Research Plan developed jointly and implemented in 1989 by the Agricultural Research Service (ARS), the Cooperative State Research Service (CSRS), the State agricultural experiment stations and other agencies. The need for a far-reaching research effort on water quality problems related to agriculture was recognized, fostering an effective partnership accomplished through collaborative administrative and research efforts among USDA, U.S. Geological Survey, the Environmental Protection Agency, and State experiment stations.

This report is the result of formal water quality research program evaluations and reviews in 1992 at Baton Rouge, Louisiana and Tucson, Arizona for the South and West regions, respectively. It portrays high priority problems needing research along with recommendations of changes in program emphasis. The recommendations reflect concerns from a broad spectrum of participants including researchers in areas of expertise relevant to water quality, technologists and specialists from the Soil Conservation Service and the Extension Service (Federal and State), and representatives of the fertilizer and pesticide industries. Similar evaluations for the North Central and Northeast projects given in the 1991 report provided guidance for this year's activities.

Abstracts for the two types of research projects of the water quality program, the Priority Components and the Selected Geographic Systems--Management Systems Evaluation Areas (MSEA) are included in the appendices of the comprehensive reports. These concise abstracts report progress of research inspired and funded in part by the President's Initiative program of ARS and CSRS. It is apparent that several of the awards "bought into" ongoing research projects yielding quicker results for use by agricultural producers. Outstanding research is underway in both programs. Onsite reviews of the MSEA projects in 1991 produced recommended changes implemented in 1991 and 1992. Adoption of results from the five major MSEA projects in the Midwest is essential. Researchers are working with education and technology transfer specialists to achieve this goal.

Interactions among meeting participants were useful from a program management view, as well as to communicate research progress and roadblocks. The significant accomplishments achieved during the past two years, and the knowledge developed through future research, will greatly enhance our understanding of fate and transport of potential contaminants in soils and water. And, these accomplishments will facilitate the adoption of economical and environmentally acceptable agricultural production systems to avoid or reduce pollution and enhance surface and groundwater quality.

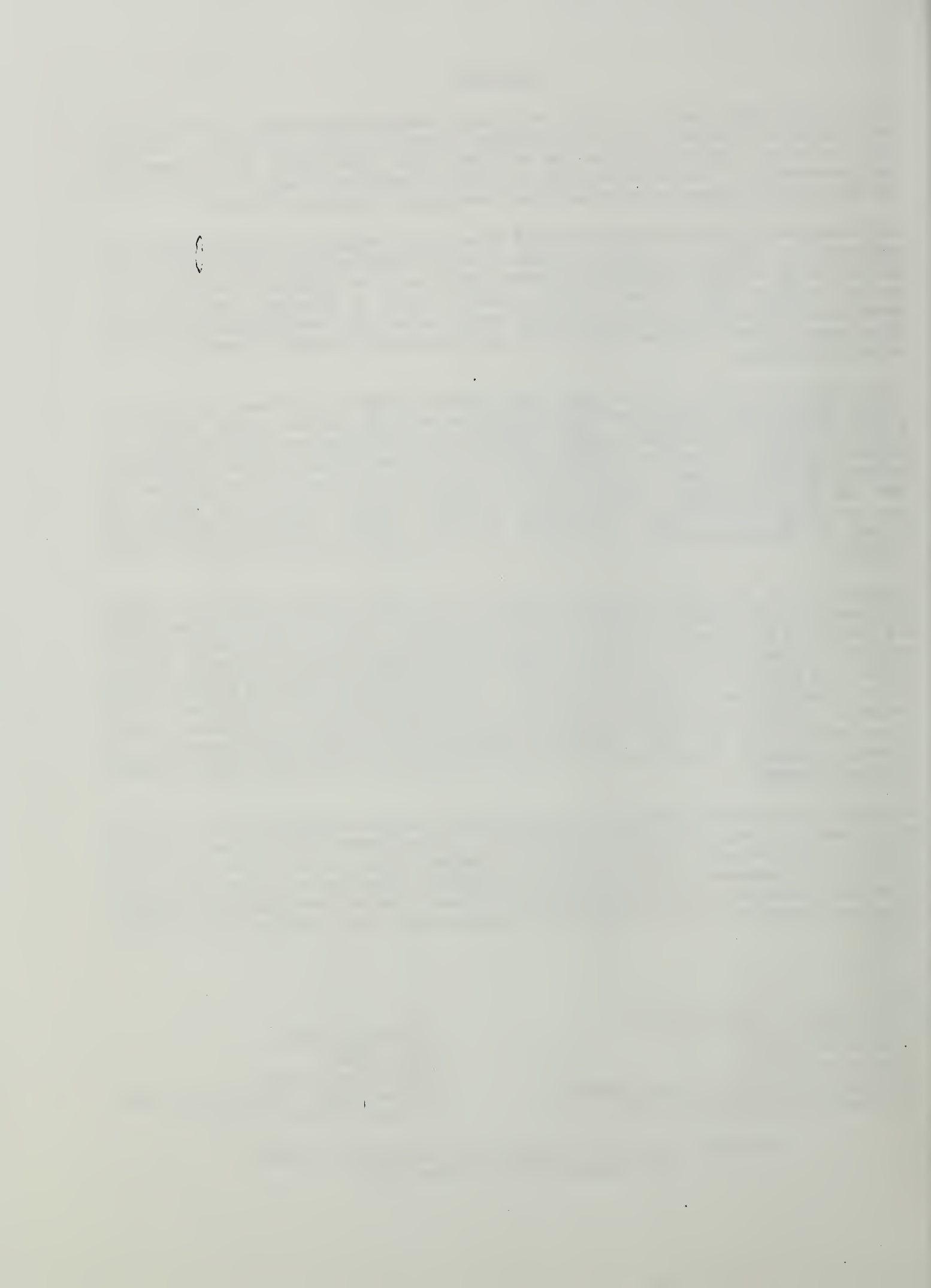


Charles B. Rumburg
Deputy Administrator
Natural Resources, Food and Social Sciences
Cooperative State Research Service



Dale A. Bucks
National Program Staff
National Program Leader, Water Quality
Agricultural Research Service

Co-Chairs, Water Quality Research and Development Committee
USDA Working Group on Water Quality



WATER QUALITY RESEARCH: THE PRESIDENT'S INITIATIVE PROGRAM REVIEW AND EVALUATION, 1992

West Region, Tucson, Arizona

BACKGROUND

The deterioration of water quality or the potential for it, resulting from the use in agriculture of certain pesticides, fertilizers, manures, and sludges, is a problem of major concern to rural and urban people and scientists. The development of effective and economically feasible technologies that avoid excessive concentrations of potential contaminants, or remediate problem conditions, requires a comprehensive understanding of what happens to chemicals and other products in soils and water and the appropriate application of information. Research in agriculture was given major impetus by new emphasis on water quality in the statement of an Initiative by The President.

"The protection of the environment and the conservation and wise management of our natural resources must have a high priority on our national agenda. But given sound research, innovative technology, hard work, sufficient public and private funds, and--most important of all--the necessary political will, we can achieve and maintain the environment that protects the public health and enhances the quality of life for us all." *President George Bush*, "Building a Better America," February 9, 1989. This document also gave three principles as the basis for the Initiative, as follows:

- "The President is committed to protecting the Nation's groundwater resources from contamination by fertilizers and pesticides without jeopardizing the economic vitality of U.S. agriculture.
- "Water quality programs must accommodate both the immediate need to halt contamination and the future need to alter fundamental farm production practices.
- "Ultimately farmers must be responsible for changing production practices to avoid contaminating ground and surface waters. Federal and state resources can provide valuable information and technical assistance to producers so that environmentally sensitive techniques can be implemented at minimum cost."

WATER QUALITY RESEARCH OBJECTIVES

The objectives are from two sources.

USDA Research Plan for Water Quality, January, 1989

1. Document the sources and amounts of potentially hazardous contaminants in groundwater which are attributable to current agricultural and forestry practices, and identify the basic processes involved in their movement through soil and into groundwater.
2. Develop new field and laboratory methods for rapidly, reliably, and inexpensively analyzing pesticide residues and for determining the rates at which water and chemicals move through soils to groundwater.
3. Develop new and modified crop and livestock production systems that substantially decrease the movement of potentially hazardous chemicals into groundwater, and determine the effects of these new systems on farm costs, changes in farm inputs, and production choices.
4. Develop simple, inexpensive, on-farm methods for disposing of pesticide containers and other hazardous wastes without contaminating groundwater.
5. Develop decision-aid systems that may be used by technical and farm management specialists, Extension agents, and farm consultants to help individual farmers select, apply, and manage profitable and environmentally sound crop and livestock production practices.
6. Evaluate economic, social, and political impacts of alternative crop and livestock production systems, policies, and institutional strategies to control groundwater contamination.

USDA Water Quality Initiative 1992 Work Plan

1. To improve and expand our knowledge of agricultural practices related to water quality.
2. To integrate that knowledge into production management systems that use economically and environmentally sound practices.

Program evaluation, to be accomplished through reporting and planning conferences, was specified in the USDA Research Plan for Water Quality (1989), the Water Quality Program Plan to support the Initiative (1989), and the USDA Water Quality Initiative Work Plans for 1990, 1991, and 1992.

All projects supported by initiative funding are considered as a total program of interrelated water quality research. The U.S. Department of Agriculture (USDA) Research Plan for Water Quality (1989) set up a structure with two general types of research activities. One type designated as Priority Components research includes a wide range from fundamental laboratory and field research to applied types of technology-driven studies, concentrating on parts or "components" of processes, practices, or systems. The other type in the 1989 Plan, Selected Geographic Systems, is represented by the long term Management Systems Evaluation Areas (MSEA) begun in 1990. This research focuses on developing and evaluating agricultural production systems for corn and soybean production areas, and is comprised of feasible combinations of results from components research, other relevant studies, and practical experience.

There are two reports resulting from the 1992 evaluation and planning sessions for the South and West Regions held at Baton Rouge, Louisiana and Tucson, Arizona, respectively. Also, a separate summary of accomplishments is available. Abstracts of the past year's research results for all new and continuing Water Quality Initiative projects funded by ARS and CSRS are included in the Appendix. All of this information was considered in the evaluation of progress and the research needs and priorities given in this report.

PRIORITY COMPONENTS

INTRODUCTION

The water quality research program review and evaluation of accomplishments and needs, funded as USDA grants and awards under the President's Initiative, was participated in by federal, university, industry, and independent scientists, 6 evaluators at each location, several observers, and speakers. There was a total of 159 projects of the Agricultural Research Service (ARS), Cooperative State Research Service (CSRS) and State Agricultural Experiment Stations (SAES), and collaborators, that constituted the accelerated and new water quality program being evaluated. In addition to these agricultural research organizations, participation included the Extension Service (ES), Soil Conservation Service (SCS), U.S. Geological Survey (USGS), the fertilizer and agricultural chemicals industries, and the private sector. Additional participants were invited.

EVALUATION and WORKSHOP OBJECTIVES

Exchange scientific and technical information among principal investigators, other researchers, program managers, and users of information.
Evaluate progress, collaboration, and coordination in USDA-funded research programs.
Identify significant results and new developing opportunities for collaboration with related programs.
Identify promising agricultural production and management systems and technologies.

PLAN and PROCESS

States in the Southern and Western Regions were involved in the April 21 to 23, and April 28 to 30, 1992 evaluation and review conference at Baton Rouge and Tucson, respectively. Principal investigators of all projects receiving Initiative funding in FY 1990 and 1991, and ongoing projects from FY 1989, were requested to prepare an abstract and report of progress, display and discuss a poster of research results and future plans, and participate in a work group(s). They discussed accomplishments and cooperatively developed priorities for problems still needing solutions, considering the goals and objectives of the Initiative. In addition, scientists in the North Central and Northeast Regions who received Initiative funds also prepared abstracts and progress reports. All abstracts were available for the 1992 meetings. They appear in the appendices of the comprehensive reports; titles and investigator names are in the appendix of the Summary report.

The scientists at the two workshops were organized into general Research Problem Area (RPA) work groups to reflect their interests and expertise, including: Chemical Fate and Transport; Transformation and Remediation--Pesticides, other Organics and Microbes; Nitrogen, other Nutrients, Wastes, and Metals; Production Management Systems; Social Sciences; Education and Technology Transfer. The last two groups interacted with each of the other four RPAs. The Education and Technology Transfer group included "users" of information representing ES, SCS, the private sector, industry, and several participants from other panels. Recommendations by the workshop panels will be utilized by CSRS and ARS in setting priorities for funding water quality projects in FY 1993 and later years.

An Evaluation Panel composed of an expert in each RPA was selected from outside the region being evaluated, except for the Social Sciences RPA in the South and the panel leaders for Education and Technology Transfer. The evaluation panelists were responsible for reviewing abstracts and reports by the scientists and other materials prepared for the meetings, and for the preparation of a report given at the beginning of the meeting. This served as the baseline for scientist debates within the individual workshops. The evaluation panelists prepared reports of the deliberations and conclusions of their respective workshops. These became the individual RPA reports.

Evaluation Panel and Work Group Guidelines

The evaluation included examining several aspects of the development of the research, whether it addresses appropriate problems in water quality, progress of the overall program, interactions with others, usefulness of results, and other points. The following guidelines were presented.

Appropriate development of program objectives and plans,
Use of the most technically advanced methods in research,
Interdisciplinary, inter-site, and inter-agency coordination where appropriate,
Adequacy of results to determine if water quality can be protected/enhanced, and how to do it,
Transferability of results or methodologies to--
 Education and technical assistance agencies, consultants, and farmers,
 Other areas and regions of the country, and
 Other management conditions in time and space.
Identify research needs and opportunities that need a different emphasis to facilitate meeting program objectives, and
Suggest changes of emphasis to meet the needs.

EVALUATION and WORKSHOP RESULTS

The Initiative program has funded excellent research at a number of Land Grant Universities, ARS laboratories, and private foundations. The principal investigators are well qualified, the overall quality of research is high, and the projects address a broad range of problems from both a subject matter and geographic viewpoint. The investigators are using "cutting edge" analytical and experimental methods. Numerous projects have made advances that can have an immediate impact on enhancing groundwater quality.

The scientists' reports for the program evaluation were based on only 6 to 24 months of results from 2- or 3-year projects funded by the President's Initiative on Water Quality. Movement and degradation of pesticides is usually a long-term problem, the solution of which requires an investment in long-term research activities. The research reported here utilized fundamental and applied methods to learn about the behavior of pesticides in soil and water. Emphasis was on widely used chemicals or ones having been detected in groundwater.

Details of work group actions are given in reports of the South and West. They contain program evaluation information and recommendations of research needs that may require special attention. Also, certain problem areas are recommended for increased emphasis to reflect the impact of research already underway. Conversely, some types of research have sufficient results to justify a redirection of emphasis.

STATE OF COMPONENTS RESEARCH

INFORMATION CONTAINED IN THIS REPORT IS CONSIDERED PRELIMINARY AND THE PRINCIPAL INVESTIGATORS SHOULD BE CONTACTED FOR DETAILS AS TO INTERPRETATION AND USE.

The processes by which chemicals used in agriculture reach surface and groundwater range in space and time from microscopic to fields and watersheds and from seconds to days and decades. Studies of these orders of magnitude require a well conceived and long-term research program. The USDA research awards have contributed to progress in solution of a broad range of problems. Much of the emphasis has been on those where short-term research was expected to yield good information.

One of the most significant accomplishments of the Water Quality Initiative is graduate student and post doctoral training. This is emphasized in several of the work groups as being an important spinoff that generates intensely trained students in broadly diverse areas--all very important to our concerns about protecting and maintaining quality of our natural resources.

To aid in understanding the technology transfer (TT) concept and to convey a classification of accomplishments from the research being evaluated, the results given under each RPA were classified as to phase of technology transfer. We have used the phase designations and explanations given by R. S. Rauschkolb¹, panel member for TT at the Tucson meetings. "Technology transfer occurs along a continuum of development and application from the initial concept of the hypothesis to final application and adoption by the practitioner. Even the most basic scientist is a benefactor of technology transfer." The status of accomplishments is identified by TT-phase to more readily assess the contribution of the accomplishments toward some perceived solution to a problem. The term technology is used in a broad sense to include information and knowledge transfer to scientists, specialists, producers, policy makers, and others.

- Phase 1. Results of research are ready for sharing with the scientific community and are presented for verification of the principle, methodology or technique.
- Phase 2. Results are ready for development and adaptive research through field validation in collaboration with scientific colleagues in Extension, Industry, SCS, *et al.* The principle is being adapted and used under a wide range of conditions in order to collect the data required to conduct an educational program to facilitate adoption in phase 3.
- Phase 3. The practices, methods, or techniques are ready for widespread implementation and commercial adoption.

¹ Rauschkolb, R. S., and L. W. Dewhirst. 1991 Technology Transfer: A University Perspective. p. 167-184. In V. J. Rhodes (ed.) Agricultural Sciences Policy in Transition. Agricultural Research Institute Publ., Bethesda, MD.

Fortunately, proposals were conceived that built upon accomplishments of earlier relevant research, and extended ongoing projects where additional funding would produce quicker or more useful results. *The Initiative program has facilitated integration of results into products for immediate application as well as a more focused assessment of remaining problems.*

Within each RPA under the subsection titled "State of Current Research", some products of the individual research projects funded by ARS and CSRS are given. The technology transfer phase (TT-_) classification and the state(s) where research was done are given for each product or accomplishment. The TT phase establishes the listing order for the accomplishments, with phase 1 given first. Where two numbers are given, the results are at different stages of development for conditions of climate, soils, chemicals, etc., which affect those results or the adoption of them.

CHEMICAL FATE AND TRANSPORT

The fate and transport of contaminants resulting from agricultural activities is a most important aspect in characterizing and understanding transport involved in non-point source pollution of water resources. The work group evaluated accomplishments of the current research program of the President's Water Quality Initiative in the West region, the research needs and opportunities, and has made recommendations on the program.

Research funded under this general RPA of the water quality program addresses the USDA program objectives as follows:

USDA Research Plan for Water Quality, 1989--Objectives 1, 2

USDA Water Quality Initiative 1992 Work Plan--Objective 1

State of Current Research

Some of the accomplishments noted for the research being done in this Region are given. The TT phase classification of each is indicated.

The retardation coefficient of the herbicide Prometryn appears to be smaller for initially moist soil conditions compared to initially dry conditions at application. Experiments using chemigation indicated that smaller amounts of Prometryn may be used as compared with the standard irrigation treatment. (AZ) [TT-1]

A new technique for measuring soil water content in the field, Time Domain Reflectometry (TDR), has been shown to be a rapid and inexpensive technique for monitoring travel times of solutes in the upper 0.5 m (20 in) of clay loam field soils. (CA) [TT-1]

Point samplers installed at the groundwater-vadose zone can be used for inexpensive monitoring of water quality resulting from using BMPs on coarse-textured soils. (CO) [TT-1]

Several data bases have been assembled for use in validation of computer simulation models. These will be shared with other investigators to multiply the utility of carefully collected field data. (AZ, CA, MT) [TT-1]

Movement of quickly degraded, non-volatile chemicals can be reduced by allowing more time for degradation in the soil surface prior to irrigation events. (MT) [TT-2]

Two passive capillary wick sampler designs were developed allowing farmers and researchers to measure water and chemical movement in the vadose zone. The samplers are inexpensive and give a direct means of developing BMPs for efficient water and chemical use without reliance on other uncertain, expensive approaches. (OR) [TT-2]

Several new software packages and corresponding manuals for solute transport models have been developed. [All are TT-2, 3]

HYDRUS predicts solute and water transport below the root zone in salt-affected soils, and considers root uptake as a function of water and salinity stresses (CA).

SWMS-2D was developed for 2-D transport of water and solutes in cropped soils (CA).

MESH has been developed to enable users to display water retention curves and hydraulic conductivity curves estimated from available soil survey data, such as texture, bulk density, organic matter and soil structure (HI).

TETRANS—Updated versions of the solute transport package were developed for both Macintosh and IBM-compatible computers and over 250 copies have been distributed to users. (CA)
Assistance was provided to four agencies in using the mobile, non-evasive, high speed salinity mapping technology in their water quality protection programs. (CA) [TT-3]
Training of graduate and post-doctoral students has occurred at those universities funded through this program resulting in critically needed development of human resources trained in water quality.

Research Needs and Opportunities

The following four major items are listed in order of priority, and are considered critical.

Quantify (measure and model) preferential flow of water and solutes including:

Identify experimentally the extent to which preferential flow penetrates below the surface,

Measure and identify soil physical, chemical, and biological parameters controlling preferential flow, and

Determine the impact of water application methods on occurrence and extent of preferential flow.

Expected result. Knowledge of the relationships between preferential flow and basic soil properties would enable (1) an improved understanding of processes by which contaminants rapidly affect groundwaters, and (2) implementation into mathematical simulation models, hence recommendations.

Develop, evaluate, reconcile, and apply in-situ and other physical and chemical measurement techniques.

Expected result. Would provide methods to assess the current status and fate of contaminants in the soil at a given point and extend or extrapolate the information to larger landscapes.

Quantify (measure and model) rate-limited chemical and biological processes.

Expected result. Since these processes vary with space and time, having this information would eliminate major uncertainties in predicting the impact of various management practices on contaminant flow and fate in the environment.

Develop methodologies for integrating processes and properties at different scales of space and time, e.g., point to pedon to landscape, and seconds to days to years.

Expected result. Would facilitate evaluation of impacts of different scale on measurement of processes involved in fate and transport of potential pollutants. It is not possible to make measurements at all scales.

These additional items are considered very important, but are not in order of priority.

Characterize the transport and transformation processes in unsaturated soil between the root zone and groundwater.

Expected result. Simulation of water and contaminant flow to the groundwater requires knowledge of the distribution of soil properties over the entire pathway, and their effects. Often, the characteristics of media between the plant root zone and groundwater are the greatest contributors to uncertainty about flow pathways.

Quantify uncertainty in model predictions.

Expected result. Elimination of uncertainty as an unknown variable in simulation models would greatly improve the ability to predict accurately. Much of the uncertainty arises from lack of knowledge of flow characteristics of the media.

Provide management decision tools by coupling transport models with available soil surveys (SCS and States) and other databases using geographical information systems (GIS).

Expected result. Would allow the practical extrapolation of results to larger scales, e.g., fields, watersheds and landscapes.

Develop realistic plant system submodels to be incorporated into transport models, e.g., plant uptake of N as a function of water, nutrient, salt, temperature, and other stresses.

Expected result. Would eliminate a major uncertainty in model simulations for conditions where plants extract water and contaminants from the root zone.

Program Management Recommendations

The workgroup made three categories of general recommendations for the future management of the research program.

Priorities for improving information exchange should include the following.

All data and models from USDA-funded projects should lead to publicly-available and documented reports.

Greater collaboration between experimental and modeling efforts should be encouraged.

Multidisciplinary research should continue to be encouraged through funding priorities.

Interagency collaboration on fate and transport research and development efforts should be increased among USDA, EPA, GS, DOE, and non Federal research entities.

The NRI research and HUA demonstration projects of Cooperative Extension and SCS should be included in the President's Water Quality Initiative review and evaluation meetings.

Participants should meet nationally according to topic area rather than by region.

Specific research priorities for emphasis in future RFPs include:

Measure and model preferential flow in additional soils,

Compare and interpret data from measurement devices for unsaturated zone transport processes,

Quantify rate-limited chemical and biological processes,

Develop methods of integrating wide ranges of time and space scales, and

Increase investigations on the influence of plant processes on fate and transport.

Additional funding should be sought for comprehensive field experiments including:

Transport and fate processes in the sub root zone and vadose zone, including the deep vadose zone, and

Coordination of the experimental and theoretical studies with data acquisition at a level suitable for model validation.

Work Group Participants

<u>Name</u>	<u>Institution</u>
Janick Artiola	University of Arizona, Tucson, AZ
Lannie Boyd	Western Assn. of Ag Exp Sta Dir, Fort Collins, CO
Mark Brusseau	University of Arizona, Tucson, AZ
Dale Bucks	ARS-USDA Beltsville, MD
Huifeng Chang	University of Hawaii, Honolulu, HI
Deanna Durnford	Colorado State University, Fort Collins, CO
Rein van Genuchten	ARS-USDA U.S. Salinity Lab, Riverside, CA
Terry Glover	Utah State University, Logan, UT
Bill Inskeep	Montana State University, Bozeman, MT
Bill Jury	University of California, Riverside, CA
Birl Lowery	CSRS-USDA, IPA, Univ of WI, Washington, DC
Burl Meek ¹	ARS-USDA, Kimberly, ID
Greg Perry	Oregon State University, Corvallis, OR
Roy Rauschkolb	University of Arizona, Maricopa, AZ
Robert Rice	ARS-USDA US Water Conservation Lab, Phoenix, AZ

Dennis Rolston²
Don Scott³
John Selker
Art Warrick
Jack Watson
Peter Wierenga

University of California, Davis, CA
University of Arkansas, Fayetteville, AR
Oregon State University, Corvallis, OR
University of Arizona, Tucson, AZ
University of Arizona, Maricopa, AZ
University of Arizona, Tucson, AZ

¹Burl Meek, Recorder for working group

²Dennis Rolston, Chair of working group

³Don Scott, Evaluation Panel member

TRANSFORMATION AND REMEDIATION Pesticides, Other Organics and Microbes

The potential for contamination of groundwater by pesticides and organics is closely related to the processes involved in the transport of these chemicals in soil and water. Transformations of chemicals must be recognized as a critical process affecting their transport and eventual fate in the environment. Only by complete degradation or biomineralization of detrimental organic chemicals can they be eliminated. Thus, transformation processes should be included as key components of any model which simulates the fate process or aids in making management decisions for remediation in maintenance of soil and water quality.

The currently-funded research projects in this area are well-focused and of excellent quality. All are making significant progress toward achieving their objectives. We can anticipate useful accomplishments in the assessment of transformation processes, in the remediation of contaminated soil and water, and in preventative management practices that minimize contamination potential. However, the number of projects devoted to transformation is still low. More effort in this area of research should be encouraged by highlighting microbial transformations as a priority area for water quality research.

Current emphasis on developing strategies for remedying contaminated soil and water and for preventing contamination should be continued. Attention should also be given to assessing spatial and temporal variations in microbial processes and to applying process-based knowledge to field- and landscape-scale management decisions. It is essential for any effort to clean up and maintain a quality environment.

Research funded under this general RPA of the water quality program addresses the USDA Program Objectives as follows:

USDA Research Plan for Water Quality, 1989--Objectives 1, 2, 3, 4

USDA Water Quality Initiative 1992 Work Plan--Objectives 1, 2

State of Current Research

Assessment of Soil/Water Quality

New molecular methods were developed to detect bacterial and viral pathogens in groundwater specifically, and with great sensitivity. These methods can be used to detect bacterial pathogens such as *Salmonella* and *Shigella* as well as viral pathogens including poliovirus.
(AZ) [TT-1]

Remediation of Contaminated Soil/Water

The potential use of genetically engineered microorganisms in the remediation of chloroaromatics has been demonstrated. An *E. coli* recombinant strain expressing a dehalogenase gene from *Flavobacterium sp.* has been constructed and shown to be inducible.
(ID) [TT-1]

A practical method to remove selenium has been developed in treatment of agricultural drainage water. Selenium is a toxic trace element when present in high concentrations. Bacteria have been isolated with the ability to reduce selenium levels in water in a cost-effective system. This process can be accelerated in a well-aerated, protein-amended system. (CA) [TT-2]

A method for on-site detoxication of pesticide residues using immobilized microbial cells has been developed. Pseudomonads have been isolated for their ability to degrade 2,4-D and parathion residues from used containers. Using packets of air-dried microbes to treat rinsates and empty containers can eliminate hazardous point sources of pesticides. (ID) [TT-2]

Best Management Practices to Minimize Soil/Water Contamination

Chemical transport and persistence were evaluated in both a no-till and conventional clean-till, furrow-irrigated management system. The no-till system conserves more water than the conventional tilled system without excessive deep percolation. (NM) [TT-2]

Timing of irrigation applications after herbicide application was shown to be an important management practice to minimize herbicide transport throughout the root zone. Phenoxy herbicides including dicamba and 2,4-D, which have short half lives under surface soil conditions, underwent significant degradation within 2 to 10 days. Delaying water application allowed degradation in the surface soil, reducing transport of these chemicals. (MT) [TT-3]

Research Needs and Opportunities

The work group selected the following as important needs to facilitate significant progress in the area of Bioremediation and Degradation.

Assessment of Soil/Water Quality

Use the Genetic approach to assess the potential of soil microbes for biomineralization of contaminants.

Assess the residence time of pesticides in the soil-water environment and quantify factors affecting this time, and rates of pesticide biomineralization.

Evaluate research approaches for elucidating factors affecting pesticide biomineralization in the subsurface of soils.

Expected result. Understanding key factors affecting the transformation processes is essential in constructing useful models to simulate and predict fate of pesticides in the environment. These research efforts should increase our knowledge base on the transformation and biomineralization of pesticides and other organic chemicals in the soil/water environment.

Remediation of Contaminated Soil/Water

Process level studies

Apply genetic engineering techniques to enhance the biomineralization processes, and

Assess and overcome factors limiting the enhancement of biomineralization processes.

Expected result These research efforts are critically needed for improving capability to remedy contaminated soil and water.

Interdisciplinary field scale studies

Integrate physical, chemical, and biological processes, using systems approaches, for the enhancement of biomineralization of pesticides and other organics.

Expected result. Bioremediation techniques must be tested for their effectiveness under natural field conditions. Successful field scale cleanup of contaminated soil and water will greatly help in establishing a quality environment.

Best Management Practices to Minimize Contaminant Pollution

Devise sound management practices that reduce pollution: Lower chemical inputs; modify the mode of their application to increase efficiency of use; reduce unwanted transport of chemicals; and enhance their biomineralization.

Risk/benefit and costs should also be included in best management practices as social and economic studies.

Expected result. The ultimate goal for these research efforts should be a cleaner environment. Effective management practices that are cost-effective and readily adaptable are essential in maintaining the quality of the soil/water environment.

Program Management Recommendations

The area of bioremediation and transformation is much neglected in the current research efforts. More effort should be encouraged in the RFP on the following.

Promote Interdisciplinary studies that integrate physical, chemical, and biological processes at the field scale. Since field studies are expensive and require long-term commitment of effort and funding, special considerations should be given to setting aside funds for this purpose.

Attention should be given to practices related to mining, forestry, and urban development as these sources cannot be separated in many situations. Current efforts in bioremediation are concentrated on agricultural practices in traditional farming.

Proper recognition should be given to the training component of these research projects that results in the development of human resources.

Work Group Participants

<u>Name</u>	<u>Institution</u>
Bob Beck	Cenex/Land O'Lakes, Agronomy St. Paul, MN
H. H. Cheng ¹	University of Minnesota, St. Paul, MN
Neal B. Christensen	New Mexico State Univ, Las Cruces, NM
William T. Frankenberger Jr. ²	University of California, Riverside, CA
Julia Hultman	University of Idaho, Moscow, ID
Bill Inskeep	Montana State University, Bozeman, MT
Cindy Orser	University of Idaho, Moscow, ID
Ian L. Pepper ³	University of Arizona, Tucson, AZ
Marc Ribaud	ERS-USDA, Washington, DC
<u>Also participating</u>	
Lannie Boyd	Western Assn Ag Exp Dir, Fort Collins, CO
Birl Lowery	CSRS-USDA, Univ of Wisconsin, Washington, D.C.
Roy Rauschkolb	University of Arizona, Maricopa, AZ
Charles Smith	Pennsylvania State Univ, Alexandria, VA
Van Volk	Oregon State University, Corvallis, OR

¹H. H. Cheng, Evaluation Panel member

²W. T. Frankenberger, Jr., Recorder for Work Group

³I. L. Pepper, Chair of Work Group

NITROGEN, OTHER NUTRIENTS, WASTES, SALTS, METALS

In many instances, funds made available through this Initiative were used to buy into major ongoing research projects relating agricultural activities to nitrogen (N), other nutrients, wastes, salts, and trace elements in surface and groundwater. This leveraging has resulted in more comprehensive research accomplishments than would have been possible otherwise. Thus, results are much more comprehensive than suggested by the titles of the eight research projects directly funded on this topic in the West. Several of these accomplishments can have a highly significant impact on the prevention of non-point pollution of waters not only in western states, but at other locations in the United States.

Research funded under this general RPA of the water quality program addresses the USDA Program Objectives as follows:

USDA Research Plan for Water Quality, 1989--Objectives 1, 3, 5

USDA Water Quality Initiative, 1992 Work Plan--Objectives 1, 2

State of Current Research

The funds from this program have resulted in the release of significant research information. Much of this research has been in progress for a decade or more.

Diagnostic technology for fingerprinting dissolved carbon, and for quantifying water movement and plant N stress have been developed and are being used. (AZ, CA, CO, OR) [TT-1]

Reduced leaching-fraction irrigation and drainage management strategies and systems have been developed. The traditional leaching requirement is excessive; the new information can reduce the pollution of both surface and ground waters resulting from irrigated agriculture. (CA, UT) [TT-2]

A calcium carbide nitrification inhibitor has been developed and extensively tested around the world. It is effective in a broad range of soils, under both saturated and unsaturated conditions, in keeping N in the ammonium form for periods up to six weeks or more, thereby decreasing nitrate leaching potential. (CO) [TT-phase 2]

Hardware and software have been developed and released for irrigated agriculture that control water application by using subsurface drip irrigation, and using mobile salinity sensors to assess salinity, nitrate, and water movement. (CA) [TT-2, 3]

Models have been developed and released

Simulation models (CA, CO, UT).

SOWACH--for estimating salt movement

TETRANS--trace element and salt movement

NLEAP--N application scheduling and leaching

The SOWACH programs and a user's manual can be obtained from the Utah Agricultural Experiment Station, Logan, UT. [TT-2]

The TETRANS program and its user's manual can be obtained from the U.S. Salinity Laboratory, Riverside, CA. [TT-2]

The NLEAP, N leaching model has been delivered to SCS and their personnel are being trained in its use. [TT-3]

The NLEAP model is published in a Soil Science Society of America book entitled "Managing Nitrogen for Groundwater Quality and Farm Profitability", Madison, WI. [TT-3]

An optimization model has been developed for irrigation scheduling. (UT) [TT-1, 2]

Research Needs and Opportunities

Looking toward the future of agriculture and non-point pollution potentials in western states, the following generalized research opportunities and needs have been identified. These are presented in a generalized form, and most include many component research topics. We envision that the limited funds available through the President's Initiative on Water Quality will support some component research which "buys into" large comprehensive research programs.

Irrigated agriculture accounts for 15 percent of arable land and contributes approximately 30 percent of the gross income from agriculture. Salinity is generally encountered in the irrigated lands in the West. The potential for reducing deep percolation and surface runoff by controlling irrigation/drainage, and therefore the movement of dissolved compounds such as nitrate and other salts, presents research opportunities for protecting water quality.

The large acreage of dryland agriculture occurs in the West, South, and North Central administrative regions of this Initiative, and has not received the attention that it deserves. While the water quality issues are similar for dryland and irrigated agriculture, the practices and techniques differ.

Research needs identified for this area include the following items.

Assess the Influences of agricultural practices on biogeochemistry of nutrients, salts, and potentially toxic trace elements (PTTE) such as As, B, Mo, Se, V, and U, and reduce surface and subsurface discharges from sources. Specific attention should be paid to source management and control, interception, reuse, treatment, disposal of drainage water, and natural remediation processes that may occur in riparian zones and the vadose zone.

Expected result. Reductions in annual quantity of nitrate, salts, and PTTE reaching the groundwater, primarily through improved water control

Develop innovative/appropriate diagnostic sensors and assessment technology to identify source of contaminants and appropriate management at all scales.

Expected result. Major improvement in site specificity for identification of problems, potential problem sites, and targeted application of fertilizers and other agricultural chemicals to dramatically enhance water quality.

Development of improved management approaches of intensive crop and livestock systems that have a high potential for contaminant of surface and ground water.

Expected result. Changes in management practices that will maintain or improve groundwater quality while maintaining an economically viable and sustainable agricultural enterprise.

Spatial and temporal identification of diffuse pollutant sources through development of GIS coupled models, assessment/diagnostic technologies, software systems, and geophysical instrument technology as related to landscape dynamics and uncertainties.

Expected result. Identification of those parts of the landscape where potential for groundwater pollution is particularly high (hot spots) and where special preventative practices need to be employed.

Develop alternative dryland cropping systems that protect water quality and replace conventional wheat-fallow sequences.

Expected result. Recommendations for improved N and water management to enhance water quality will result from the research.

Urban-Industrial/agriculture interactions as affected by competition for water and land resources, residential and industrial chemical use, urban waste disposal on agricultural lands, concentrated pollution sources resulting from urban influence, and synergistic/antagonistic impacts on ecology.

Expected result. Improved control of groundwater pollution resulting from pressure created by urban-agricultural interactions and conflicts, including not only chemical discharges, but also social/economic factors affecting land use.

Devise integrative strategies and systems for the control of pollution from irrigated lands, including related policy constraints developed in collaboration with policy specialists. The strategies must be appropriate to constraints of large scale geohydraulic units.

Expected results. More effective strategies and acceptable systems for water quality enhancement.

Program Management Recommendations

Unique to western agriculture. Compared to other regions of the United States, there are two groups of factors that are rather unique that need to be specifically emphasized in program planning and management for water quality research in the western region.

Water quality and water conservation. Water supply, management, and quality, are factors of prime importance to irrigated agriculture, whereas efficient soil storage and utilization of precipitation is the first factor of concern for dryland crop production.

Problems associated with soil salinity (total dissolve solids). In a high percentage of the soils in the West, the presence of naturally-occurring salts including potentially toxic trace elements creates special problems for water quality.

Thus, our research needs address various aspects of these two concerns as they impact or are impacted by water quality. We recommend they be emphasized in future RFPs and awards of funds for water quality research in the Western Region.

Technology transfer opportunities. Because of the potential significance of the impact of several accomplishments listed in State of Current Research, in addition to much relevant information from research supported by other sources, it is *important that technology transfer teams be organized to implement these research results* for prospective users of this information.

For example, to get widespread adoption in the use of NLEAP, it would be well to form technology transfer task forces not only with Extension Service, SCS, EPA, and other educational and regulatory agencies, but also directly with consultant organizations and the fertilizer industry. Ultimately the aim of this task force would be to get this model onto the computers of fertilizer dealers, consultants and farmers to provide factual information on nonpolluting N fertilizer requirements for a given field under a given set of management conditions.

Work Group Participants

<u>Name</u>	<u>Institution</u>
F. J. Adamson	ARS-USDA, Phoenix, AZ
D. L. Carter	ARS-USDA, Kimberly, ID
L. Dudley ¹	Utah State University, Logan, UT
R. F. Follett ²	ARS-USDA, Ft Collins, CO
R. Fuji	US Geological Survey, Sacramento, CA
Z. Hinedi	University of California, Riverside, CA
A. Mitchell	Oregon State University, Madras, OR
G. Perry	Oregon State University, Corvallis, OR
S. Petrie	Unocal Agriproducts, Boise, ID
C. J. Phene	ARS-USDA, Fresno, CA
J. F. Power ³	ARS-USDA, Lincoln, NE
J. D. Rhoades	ARS-USDA, Riverside, CA
M. Shaffer	ARS-USDA, Ft Collins, CO
D. Stockbridge	SCS-USDA, Ft Worth, TX
R. J. Suppalla	University of Nebraska, Lincoln, NE
J. Thies	Oregon State University, Corvallis, OR

¹L. Dudley Recorder of Work Group

²R. J. Follett, Chair of Work Group

³J. F. Power, Evaluation Panel member

PRODUCTION MANAGEMENT SYSTEMS

The area of production management systems is very broad encompassing many aspects of water quality research ranging from detailed models to field research. The impossibility of field experiments to address the myriad of possible production systems has necessarily led to the widespread adoption of models. Thus considerable discussion centered on various aspects of water quality models. Ongoing research in this area relies heavily on models.

Research funded under this general RPA of the water quality program addresses the USDA Program Objectives as follows:

USDA Research Plan for Water Quality, 1989--Objectives 3, 5, 6

USDA Water Quality Initiative, 1992 Work Plan--Objectives 1, 2

State of Current Research

Several noteworthy accomplishments resulting from production management systems research were identified and are listed below.

Guidelines for monitoring pesticide leaching are being developed. Inherent variability in natural soil properties combined with analytical difficulties associated with pesticide measurement in soils make characterization of vadose zone transport difficult. Shallow groundwater samples may be useful for assessment of pesticide leaching. (CO) [TT-1]

A root zone water quality model incorporating preferential flow will aid in understanding chemical movement through the soil profile. (CO) [TT-1]

Scheduling the application of herbicides based on weed population data is the basis of a model. Field tests indicate an overall reduction of 10 to 15 percent in the amount of herbicide used, thus reducing the potential for polluting soils and water while increasing net returns from the crop production system. (CO) [TT-1,2]

An approach for identifying nitrate leaching hot spots has been developed using the NLEAP model and GIS technology. It is being field tested in the Northern Colorado Water Conservancy District. (CO) [TT-2]

The elements of an expert system for advising producers on the proper amount of nitrogen to apply for irrigated corn production in Colorado have been developed. The system recommendations ensure adequate nitrogen for the crop without having an excess that can leach toward ground water. (CO) [TT-2]

Alternatives can be ranked using a multiobjective decision model for scoring management practices on farmland. Different weights can be placed on various model outputs such as ground and surface water quality, nutrient leaching, and net income. The weighted outputs are then scaled and combined into an overall score. This allows one to replace subjective decision making with objective criteria. Alpha testing of the model will be underway during the summer of 1992. (AZ) [TT-2]

Contaminant source in well water can be screened. For uniform aquifer conditions, a pumping and sampling procedure has been developed that allows one to deduce if the source of a contaminant in well water originates from a point source at or near the well or a non point source. This information provides guidance for remediation of contamination. (AZ) [TT-2]

A relatively inexpensive anemometer will produce wind data that result in evapotranspiration (ET) estimates within two percent of those from more precise but costly devices. Estimation of ET is a key element in water management models. This reduced cost relaxes a constraint to the use of real time irrigation scheduling, a practice which can reduce runoff and N leaching to groundwater. (CO) [TT-2]

Prescription farming research has shown more efficient use of nutrients for a field. By matching the fertilizer applied for dryland wheat and barley to the actual crop requirement based on the current nutrient level of the soil and the soil's yield potential, a benefit of from \$5 to \$15 per acre can be realized. The overall amount of fertilizer used is about the same as the amount applied under conventional farming; however, by matching the application to the crop requirements for different soils across a field, the potential for nutrient leaching is greatly reduced. (MT, MN, ME, WA) [TT-1, 2, 3]

High Irrigation water use efficiency reduces leaching/pollution. A number of projects are verifying that irrigation practices resulting in high water use efficiencies also are effective at reducing or eliminating groundwater pollution by potentially hazardous agricultural chemicals and salts. For example, every inch of excess irrigation water applied to corn can result in about 10 lb/A of N leached. (CO, UT) [TT-2,3]

Research Needs and Opportunities

Among the remaining groups of research needs are those listed below.

Develop, test and make operational new technologies

Apply new technologies in "precision agriculture": neural networks, remote sensing, global positioning satellites (GPS), GIS, etc.,

Improve sensors and application technologies for water and chemical management, and

Field assessment of water quality conditions.

Expected result. Would improve the efficiency of agricultural inputs such as water, nutrients, and pesticides, and reduce the potential for environmental degradation and the possibility of chemical residues on/in food products.

Model validation and adaptation

Field validate water/solute transport models,

Develop simplified methods to apply complex simulation models,

Quantify statistical confidence in model results,

Integrate models for real time management decisions including chemical, biological and physical processes,

Match model complexity to needs for management applications, and

Improve data bases (i.e., soil and climatic) for water quality management models.

Expected result. Would improve the utility of and confidence in models that facilitate evaluating many environmental, physical, and chemical management variables that would be impossible to assess through experimentation. This could include evaluating uncertainties in weather and other controlling variables to estimate probabilities of various outputs rather than a mean, and to be more site and situation specific in recommending agricultural management approaches.

Scales of measurement and extrapolation

Extrapolate experimental and model results across temporal and spatial scales, i.e., strategies to go from point or plot-size to field and basin scales, and from seconds, minutes or hours, to days and years.

Integrate preferential flow. Quantify the importance/effects of preferential or by-pass flow in nutrient and pesticide transport and hence management implications. Determine the needed field measurements and models for use in decision aids.

Predict changes in aquifer concentrations from contaminant loadings.

Expected result. Improved ability to assess on a field, watershed, or regional basis the environmental and economic impacts of alternative agricultural management practices, incorporating effects of improved accuracy in estimating water quality impacts.

Management and risk

Evaluate the performance of BMPs in the field for selected soil and weather conditions.

Determine risk as related to consequences of alternative management decisions.

Expected result. Improved ability to evaluate the impact of agricultural management decisions and to communicate this information to producers and the general public.

Waste utilization

Evaluate alternatives for animal waste management and integrate into management decision aids.

Evaluate impacts of "safe" municipal and industrial wastes integrated into management decision aids.

Expected result. Improved use of wastes in agricultural production in environmentally acceptable options, reduced land fill volumes required for disposal of certain municipal and industrial wastes, thus, reduced point sources of potential water pollution.

Program Management Recommendations

The major recommendation concerning management, in the water quality research initiative, is to increase emphasis on systems research addressing multiple objectives and multiple user groups, such as producers, consumers/public, action agencies, researchers, agribusiness, etc.

Work Group Participants

<u>Name</u>	<u>Institution</u>
Lannie Boyd	Western Ag Exp Sta Dir Assn, Fort Collins, CO
Bert Clemmens	ARS-USDA, Phoenix, AZ
Deanna Durnford	Colorado State University, Ft. Collins, CO
Terry Glover	Utah State University, Logan, UT
Duane Griffith	Montana State University, Bozeman, MT
Tom Haan ¹	Oklahoma State Univ, Stillwater, OK
Dale Heermann ²	ARS-USDA, Ft. Collins, CO
Maurice Horton	CSRS-USDA, Washington, DC
Jeff Jacobsen	Montana State University, Bozeman, MT
Jim Loftis ³	Colorado State University, Ft. Collins, CO
Birl Lowery	CSRS-USDA, Univ of Wisconsin, Washington, DC
Steve Oberle	Iowa State University, Ames, IA
Ed Schweizer	ARS-USDA, Ft. Collins, CO
Marv Shaffer	ARS-USDA, Ft. Collins, CO
Jeff Stone	University of Arizona, Tucson, AZ
Ray Supalla	University of Nebraska, Lincoln, NE
Howard Thomas	SCS-USDA, Portland, OR
Dale Westermann	ARS-USDA, Kimberley, ID
Dennis Wichelns	Univ Rhode Island/Univ of CA, Kingston, RI

¹Tom Haan, Evaluation Panel member

²Dale Heermann, Chair of Working Group

³Jim Loftis, Recorder for Working Group

SOCIAL SCIENCES

The socio-economic dimension of the President's Water Quality Initiative encompasses four critical components.

Evaluations of the farm level consequences from alternative technologies and management practices for improving water quality;

Analyses of the economic impacts on rural communities from actions to improve water quality;

Assessments of how producers are likely to respond to education, incentives and other public policies designed for improving water quality; and

Development of decision aids for use by producers in meeting environmental objectives in an increasingly complex production setting.

Accomplishing the above requires the integration of studies in economics, sociology, soil science, agricultural engineering, plant science and other disciplines. Social scientists must work closely throughout the research and implementation process with their colleagues in other disciplines and with staff from regulatory and action agencies to ensure that the most relevant options are considered and that all assessments are reflective of the best that science has to offer.

Research funded under this general RPA of the water quality program addresses the USDA Program Objectives as follows:

USDA Research Plan for Water Quality, 1989--Objectives 3, 4, 5, 6

USDA Water Quality Initiative, 1992 Work Plan--Objectives 1, 2

State of Current Research

Although social scientists in the western states have responded more aggressively than their counterparts in all other regions, the amount of on-going work is still well below what is necessary to meet program objectives. Significant efforts are underway which address the farm level consequences of alternative practices, and some projects address the importance of incentives as a method of implementing a more environmentally sensitive agriculture.

Despite the limited scope of the present program, social science projects have produced several important findings and accomplishments. The following generalizations highlight the key elements. Information from the first two studies is available to integrate into decision aids.

There may be important tradeoffs between nitrate leaching and other environmental objectives, such as sedimentation and erosion. (OR, WA) [TT-2]

Water quality can be improved in some areas by facilitating the voluntary transfer of water rights to urban use through water markets. (UT) [TT-2]

Four factors explain much variability in the level of nitrogen contamination of water wells in dryland cropping systems in the Northern Great Plains: soil type, land use, potential evapotranspiration, and slope. (MT) [TT-2]

Producers can simultaneously reduce nitrate leaching and improve farm income on many sprinkler and furrow irrigated farms of the Pacific Northwest. (OR, WA) [TT-3]

The most cost effective method of reducing nitrate leaching in the surface water (flood irrigation) areas of the Pacific Northwest appears to be reduced water applications. (OR, WA) [TT-3]

Production cost incentives induce rapid adoption of environmentally sensitive technologies if combined with education and technical assistance. (CA, RI, DC) [TT-3]

Research Needs and Opportunities

There is, however, no work underway which addresses the impact of water quality programs on the agricultural supply and processing industries, or on any other groups in rural communities. Also, little attention has been given to assessing a wide range of public policies and other methods of inducing the adoption of best management practices for improving water quality. Perhaps most importantly, additional projects are needed to address the gaps in our knowledge base concerning producer behavior.

Incorporate a wider range of technical and managerial alternatives into analytical models.

Expected result. This would allow a more accurate assessment of input substitution and enterprise choice adjustments likely to result from environmental constraints or incentives.

Analyze producer adoption behavior including consideration of profit risk, labor constraints (convenience), environmental attitudes, technical knowledge, etc.

Expected result. A better understanding of producer behavior, which is essential as a guide for developing technologies that can and will be adopted by producers. It should provide a basis for more accurate assessments of what producers are most likely to do in response to new economic incentives or other environmental policies.

Analyze the economic impacts on agricultural dependent communities from water quality programs which change cropping patterns and input use at the farm level.

Expected result. Improved environmental policies which recognize the potential adverse impacts on rural communities from farm level changes in agricultural production and input use.

Incorporate realistic field conditions into analyses of the technical and managerial alternatives for improving water quality. This will require close working relationships with other scientists as laboratory and experimental work is undertaken to develop and assess alternatives which are eventually implemented at a field level.

Expected result. Improved accuracy and credibility in the development and implementation of best management practices, and improved evaluations of managerial and policy alternatives.

Analyze the impact of agricultural policies on cropping patterns, input use, and other water quality factors, and on the potential for further integration of environmental and farm income objectives in U.S. Agricultural Policy.

Expected result. More effective agricultural policies and an increased likelihood that water quality can be improved through voluntary educational and incentive based programs.

Program Management Recommendations

Place greater emphasis on the breadth of expertise represented on the research teams in proposals. This will enhance the likelihood that scientists pursue alternatives which have potential for implementation, and will facilitate the eventual adoption of best management practices by producers.

Add social scientists to ARS research staffs, or strongly encourage interdisciplinary and interagency research. The goal would be to involve social scientists in appropriate collaboration, which would broaden the overall effectiveness of ARS research.

Encourage more active working relationships with regulatory and action agencies to facilitate the development of improved public policies.

Amend RFP guidelines to reflect more specifically a need to evaluate alternative public policies for producing a more environmentally sensitive agriculture. Include the use of incentives, pollution certificates, and other efficiency based mechanisms, as alternatives to regulation. Hopefully, this would broaden participation of qualified scientists.

Continue to support and encourage regional and national research planning and reporting meetings which bring together scientists from numerous disciplines, regulatory, and action agencies.

Work Group Participants

<u>Name</u>	<u>Institution</u>
Dale Bucks	ARS-USDA, Washington, DC
Terry Glover	Utah State University, Logan, UT
Duane Griffith ¹	Montana State University, Bozeman, MT
Greg Perry	Oregon State University, Corvallis, OR
Marc Ribaud	ERS-USDA, Washington, DC
Ed Schweizer	ARS-USDA, Ft Collins, CO
Charles Smith	Penn State University, Alexandria, VA
Raymond Supalla ²	University of Nebraska, Lincoln, NE
Howard Thomas	SCS-USDA, Portland, OR
Dennis Wichelns	Univ of Rhode Island, Kingston, RI

¹Duane Griffith, Recorder for Work Group

²Raymond Supalla, Evaluation Panel member and Chair of Work Group

EDUCATION AND TECHNOLOGY TRANSFER

An important effect of the program is the training of graduate and post-doctoral students at those universities funded through this program. Critically needed human resources technically trained in water quality are very important for TT agencies and industry, as well as for research.

It is useful for an evaluation of the technology transfer status of progress in various projects that identifies those results of research to be recommended for use in the solution to a problem. It is from these efforts that future corrective practices develop and are widely adopted. A great deal of collaborative/developmental and adaptive research is required before principles and technology presented here are ready for education of the target practitioner audience pursuant to adoption.

State of Current Research

Examples of accomplishments were classified by the panels as ready for use by TT agencies and/or adaptive on-farm trials for site specific modifications.

- New software packages and manuals for several solute transport models. [TT-2, 3]**
- A mobile, high speed salinity mapping technology is being used by 4 agencies in their water quality protection programs. [TT-3]**
- Hardware and software have been released for subsurface drip irrigation with sensors to assess salinity, nitrate, and water movement. [TT-2, 3]**
- Delayed irrigation after herbicide application minimized dicamba and 2,4-D transport. Time allowed degradation in the surface soil. [TT-3]**
- Prescription farming can increase efficient use of nutrients. By matching fertilizer use to crop requirements for different soils in a field, the potential for nutrient leaching to groundwater is greatly reduced. This practice is being used successfully. [TT-1, 2, 3]**
- High irrigation water use efficiency reduced groundwater pollution by potentially hazardous agricultural chemicals and salts. Every inch of excess irrigation water on corn can result in about 10 lb/a. of N leached. [TT-3]**
- Large production cost incentives, such as tiered pricing of irrigation water, induce rapid adoption of water conserving and environmentally sensitive technologies when combined with education and technical assistance programs. (CA, RI, DC) [TT-3]**

Needs and Opportunities

There is a perception and evidence among the investigators present at this review that collaboration on interagency and/or interdisciplinary teams frequently is not required, recognized or rewarded by administrators and even one's scientific peers. There are needs and opportunities for the scientific community, administrators and funding agencies to enhance the education and technology transfer process by supporting such cooperative efforts.

Mechanisms should be provided to recognize, support and reward members of an investigative team whose objective is the planning, design, implementation feedback, and adoption of research accomplishments to solve problems of water quality. As an example, it has been recently learned that the University of California Academic Senate has adopted a systemwide policy identifying non-discovery research and technology transfer as appropriate activities for merit and promotion.

Develop mechanisms for utilizing high tech communications networks for sharing results through electronic mail, joining standardized databases and libraries to exchange information products.

Fund projects that synthesize results from research projects into methodology or technology for adoption by the practitioner.

Utilize expert systems and associated heuristic knowledge, and co-integrate products of research into a management decision-making mode for the practitioner.

Fund studies on how practitioners make decisions to adopt technology that arises from research accomplishments.

Program Management Recommendations

Investigative teams should include appropriate representatives from the technology transfer and user audience in the initial planning, design, and implementation phases. And later they will provide feedback for modification and adoption, e.g. persons from USDA--ARS, CSRS, ES, SCS--and USGS, EPA, and cooperating Land Grant Colleges along with industry and producers.

Research proposals need to include a statement by the project team regarding the nature of their anticipated accomplishment(s) and where they lie along the technology transfer continuum.

Research proposals should contain planned marketing strategies that encourage adoption. Proposal budgets need to identify funds that will lead to adoption of research products and results. There is a lack of marketing the research products and results.

The project proposal should identify the best mechanism for accomplishing the transfer of technology and required funding from cooperators to support the research and technology transfer activities necessary for adoption.

A research report must provide an application summary which indicates the problem(s) the research was to solve and the potential application of results. They must indicate the technology transfer phase(s) of the project accomplishments and identify actions required to achieve adoption.

Create a technology adoption incentive program for producers who apply new systems or practices. The program would provide funds under a short term agreement to insure the producer against losses, if any, incurred during adoption of best management practices to protect or improve water quality.

Work Group Participants

<u>Name</u>	<u>Location</u>
Bob Beck ¹	Cenex/Land O' Lakes, St. Paul, MN
Landis L. Boyd	Western Ag Exp Sta Directors, Fort Collins, CO
Dale A. Bucks	ARS-USDA, Natl Prog Staff, Beltsville, MD
David L. Carter	ARS-USDA, Kimberly ID
Neal Christensen	New Mexico State University, Clovis, NM
Maurice Horton	CSRS-USDA, Washington, DC
Bill Inskeep	Montana State University, Bozeman, MT
Jeff Jacobsen	Montana State University, Bozeman, MT
Bill Jury	Soil & Envir Sci, Univ of California, Riverside, CA
Alan Mitchell	Oregon State University, Madras, OR
Steve Oberle	ES/CES-USDA, Iowa State University, Ames, IA
Steve Petrie	Unocal Agriproducts, Boise, ID
R. S. Rauschkolb ²	University of Arizona, Maricopa, AZ
John Selker	Oregon State University, Corvallis, OR
Dave Stockbridge	SCS-USDA, Natl WQ Tech Dev Staff, Ft. Worth, TX

¹Robert Beck, Recorder of Work Group

²R. S. Rauschkolb, Evaluation Panel member & Chair of Work Group

APPENDIX

THE PRESIDENTS INITIATIVE on WATER QUALITY

APPENDIX

Abstracts of Research Progress, 1992 Report

The following abstracts are based on current results of research funded in part by water quality initiative awards by ARS and CSRS. The additional projects have inspired very useful research for improved management of potential pollutants from agriculture.

ARIZONA FARMSTEAD CONTAMINATION OF GROUNDWATER. H. Bouwer, A. J. Clemmens, USDA-ARS, Phoenix, AZ; T. Maddock, University of Arizona. Report Period: 8/91 - 2/92.

Model studies are carried out to determine if contamination of groundwater is due to point or non-point sources. With a point source, contaminant concentrations in well water should decrease with continuous pumping. For non-point sources, they should stay about the same. "Disappearance" curves are being developed to estimate the extent of the point-source contamination and to develop the best strategy for remediation. For non-point source contamination, deepening of wells may improve well water quality but the contaminant eventually may show up again. Model studies are performed to see how long this may take.

ARIZONA NITROGEN FERTILIZER AND WATER TRANSPORT UNDER 100% IRRIGATION EFFICIENCY. H. Bouwer, F. J. Adamsen, D. J. Hunsaker, R. C. Rice, and F. S. Nakayama, USDA-ARS, Phoenix, AZ. Report Period: 2/91 - 2/92.

Cotton was grown using level basin flood irrigation in 1991, and wheat planted in the winter of 1992. Chemical tracers were applied with each irrigation. Current standard practices, and surface application of fertilizer based on soil test levels, petiole nitrate-N feedback, and leaf chlorophyll content, and fertilizer application in the irrigation water were evaluated in combination with 100% and 80% irrigation efficiency. One of the chemical tracers, m-trifluorobenzoic, caused the cotton leaves to curl and bolls to abort. The plants eventually overcame this effect but yields were reduced in the affected plots. A greenhouse study was initiated to determine whether the tracer or some impurity in the materials used caused the damage to the cotton. Preliminary results from the greenhouse study showed no damage to seedlings when grown in potting mixture. Evaluation of the tracers in field soil has been started.

ARIZONA NONIDEAL TRANSPORT OF PESTICIDES IN SOILS. M. L. Brusseau, University of Arizona. Report Period: 9/1/91 - 2/1/92.

The past five months, which represent the beginning of this grant, have been used primarily to set up and test the miscible displacement systems that are to be used to accomplish the stated objectives. Two systems are operative, one for transport experiments performed under water-unsaturated conditions and the other for saturated conditions. The results of preliminary experiments demonstrate that the systems are operating effectively and that they will successfully provide sorption and transport data. In addition, they have also been shown useful for investigating coupled processes, in this case the effect of simultaneous sorption and biodegradation on transport. Another activity performed over the initial period of the project was an evaluation of the usefulness of quantitative structure activity relationship (QSAR) analysis for investigating the mechanistic aspects of sorption. Based on the results, the polymer analogue is suggested as the phenomenological model of choice for investigating and evaluating sorption mechanisms for soil systems.

ARIZONA DEVELOPMENT OF A PROTOTYPE DECISION SUPPORT SYSTEM FOR WATER QUALITY MODELS. L. J. Lane, D. S. Yakowitz, USDA-ARS; J. J. Stone, P. Heilman, B. Imam, University of Arizona. Report Period: 4/90 - 2/92.

A prototype Decision Support System to evaluate and rank alternative management practices on farmland with respect to surface and groundwater quality has been developed and is currently being implemented. The simulation model has been configured and coded with the following components: hydrology, erosion/sediment, pesticide (from GLEAMS), nutrient (from CREAMS), crop growth (from EPIC) and economics (from CARE). The multi objective decision model has

been implemented and combines graphical scoring functions and a new ranking method that removes much of the subjectivity that dominates other methods. The user-interface and data bases are currently under development. Model verification and validation is in progress.

ARIZONA MOLECULAR METHODS FOR EVALUATION OF MICROBIAL QUALITY OF GROUNDWATER. I. L. Pepper, C. P. Gerba, S. D. Pillai, University of Arizona. Report Period: 7/1/90 - 2/20/92. Primers from the lamB gene allow amplification of DNA from fecal coliform indicator organisms via polymerase chain reaction (PCR). Primers from the phoP gene and Hin and H-li genes allow specific detection of Salmonella spp. The lamB primers were used for analysis of indicator organisms in distilled water. Detection was by Et Br or gene probe. Water samples were processed through a Sterivex filter unit, and concentrated by either membrane filtration, or cell pelleting with the latter method giving increased levels of coliform detection. Sensitivity decreased in groundwater samples, and was dependent on water quality. The lowest number of cells detected was 104 CFU's per 2 liters.

ARIZONA MANAGEMENT PRACTICES AND PREFERENTIAL FLOW TRANSPORT OF AGRICULTURAL CHEMICALS. A. W. Warrick, John E. Watson, Jon P. Chernicky, David O. Lomen, University of Arizona. Report Period: 6/89 - 12/91.

A non-adsorbed tracer (bromide), a soil adsorbed tracer (FD&C Blue No. 1 Dye) and a moderately adsorbed herbicide (Prometryn) were applied to field plots by injection into a pressurized water delivery system. The impact of initial soil moisture conditions on preferential flow transport was investigated by including plots that had not received irrigation water for a substantial length of time and plots that were subject to a 10 cm irrigation water application immediately prior to the tracer and herbicide applications. A backhoe was used to excavate trenches in each plot. Soil samples were collected in a grid configuration immediately adjacent to each other from each trench. Samples were extracted to determine concentrations of bromide, dye and herbicide. Profiles of concentrations with depth have been compared to modeled data using a convection-diffusion solution and best-fitted to estimate retardation and dispersion coefficients. Results were generally reasonable for bromide, but more erratic for the prometryn.

ARIZONA THE PERSISTENCE OF PREFERENTIAL FLOW DURING AN INFILTRATION EVENT. A. W. Warrick, John E. Watson, Janick Artiola, Jon P. Chernicky, Univ of AZ. Rpt Per: 7/91 - 2/92.

A field research plot has been set up at the Maricopa Agricultural Center. Placement of the sampling devices was completed in February 1992. The treatments are soil condition at the time of herbicide and tracer application. Included are a. Non-cropped, surface-tilled and b. cropped-enhanced macropore development. Tracers will be used to differentiate between portions of the irrigation water so that the pulse containing the herbicides can be distinguished from the herbicide free pulse. Conservative tracers to be used include bromide as KBr and three fluorinated benzoic acids. Solution sampling equipment installed include gravity-fed, hollow glass blocks (pan lysimeters) and suction lysimeters.

ARKANSAS & TEXAS MODELING WATER QUALITY IMPACTS OF SURFACE-APPLIED BROILER LITTER TO IDENTIFY BMPs. T. C. Daniel, D. R. Edwards, University of Arkansas, and R. H. Griggs, Texas A&M University. Report Period: 7/90 - 3/92.

Runoff data are being evaluated from three rainfall simulation runs conducted at two intensities on three wastes. Solute movement through the vadose zone is being monitored continuously with suction cup and pan lysimeters under constant vacuum. Concentrations of nutrients in the runoff were higher than literature values, especially dissolved phosphorus. Nitrate concentration of the soil water is directly related to application rate. BMPs should focus on timing of manure application and limiting dissolved phosphorus in the runoff. During the reporting period, eight manuscripts were submitted for publication and seven presentations conducted.

ARKANSAS OPTIMIZING ON-FARM DISPOSAL OF PESTICIDE RINSATES. T. L. Lavy, J. D. Mattice, D. C. Wolf, R. E. Talbert, University of Arkansas. Report Period: 9/89 - 2/92.

An activated charcoal filtration unit has been designed which effectively removed the pesticides atrazine, benomyl, carbaryl, fluometuron, metolachlor, and trifluralin from pesticide-laden wastewater. The system is simple in design and use. Several common dyes have been studied which could be used as visual assays to determine the remaining adsorptive capacity of charcoal used in an activated charcoal filtration system. Studies assessing the biodegradability of charcoal-bound pesticides suggest that the age of spent charcoal will play an important role in controlling the bioavailability of sorbed pesticides. Options to incinerating spent charcoal are being investigated.

ARKANSAS DEVELOPMENT OF A GEOGRAPHIC INFORMATION SYSTEM TO ANALYZE NITRATE CONTAMINATION FROM THE LAND APPLICATION OF POULTRY LITTER. H. D. Scott, M. J. Cochran and W. F. Limp. University of Arkansas. Report Period: 9/89 - 2/92.

A geographical information system has been developed for the Muddy Fork watershed in northwestern Arkansas. Primary and secondary databases along with site data were developed for the watershed. Statistical correlations and regressions were used to relate landscape features to the nitrate-N concentrations in wells and springs. Soil drainage classification and distance from a poultry house were the statistically significant landscape parameters. A deterministic computer model has been developed to describe the fate of N after the application of poultry litter to pasture. The model predictions compared well with the results obtained in a 2-year field study. An economic model was also developed for the watershed based on three scenarios. The environmental and economic scenarios indicated that profits were 64% and 95% of the baseline scenario, respectively.

CALIFORNIA WATER QUALITY MANAGEMENT ON THE WESTSIDE SAN JOAQUIN VALLEY. J. E. Ayars, C. J. Phene, H. I. Nightingale, G. S. Banuelos, USDA-ARS, Fresno, CA. Report Period: 12/90-2/92.

The demonstration sites were selected and installation of subsurface drip systems on two 30 acre sites was completed in the spring of 1991. Processing tomatoes and cotton were grown during 1991. In addition to the drip system, surface irrigation using automated lay-flat tubing and gated aluminum pipe were used. Tomato yields were about 19% higher in the drip plots than in the furrow irrigated plots with about 10% less water being used in the drip plots. Cotton yields were comparable in both the drip and furrow irrigated plots. A field day co-sponsored by the California DWR and Westlands Water District was held at the site to display and discuss subsurface drip technology to a group of 50 people.

CALIFORNIA DISSOLVED ORGANIC MATTER IN SOIL AND NATURAL SYSTEMS AND ITS ROLE IN GROUNDWATER POLLUTION. A. C. Chang, Z. R. Hinedi, and R. W. K. Lee, University of California, Riverside. Report Period: 7/90 - 2/92.

A set of 33 water samples was obtained from wells located in the Chino-Corona dairy area. The $\text{NO}_3\text{-N}$ and chloride concentration in the water samples ranged from 3.27-113 and 4.00-230 mg L^{-1} , respectively. Each sample was double filtered then freeze dried. The residue was suspended in heavy water (D_2O) then analyzed by ^1H Nuclear Magnetic Resonance. The spectra obtained were highly resolved often showing multiple coupling. A two-dimensional ^1H - ^1H NMR experiment was run on one sample to detect coupled spins. The $\text{NO}_3\text{-N}$ contaminated groundwater exhibited a distinctively different dissolved organic matter (DOM) matrix than the background water. The spectra will be analyzed using a pattern recognition algorithm. In a laboratory study we examined the association of DOM with $\text{C}_6\text{H}_5\text{F}$. Pulsed Field Gradient Spin Echo NMR was used to determine the self diffusion (D) coefficients of $\text{C}_6\text{H}_5\text{F}$, DOM molecular species, and $\text{C}_6\text{H}_5\text{F}$ -DOM. Based on their D values, at least two $\text{C}_6\text{H}_5\text{F}$ -DOM complexes could be distinguished from the free $\text{C}_6\text{H}_5\text{F}$.

CALIFORNIA ASSESSMENT OF SOIL SALINITY AND SALT-LOADING TO GROUNDWATER. D. L. Corwin, J. D. Rhoades, S. Lesch, P. J. Vaughan. Report Period: 1/91 - 2/92.

An integrated approach to estimating soil salinity profiles and solute loading to the groundwater was developed and implemented in a study area comprising 6000 acres in the central valley of California. Soil salinity associated with both mobile and immobile water phases has been measured

throughout the area using both a four-electrode resistivity technique and an electromagnetic induction instrument. 1184 soil samples were taken in the area and were analyzed for saturation percentage and EC_e . Detailed chemical analyses of pH_e , HCO_3 , Cl , SO_4 , NO_3 , Na , K , Ca , Mg , SAR and B were performed for 280 soil samples. These data, along with irrigation history and other kinds of data have will be used as input to the TETrans solute transport model which calculates solute redistribution in the vadose zone and solute loading to the groundwater. Updated versions of the TETrans solute transport package were developed for both Macintosh and IBM-compatible computers. Over 250 copies have been distributed to users. A GIS database incorporating TETrans is under development for the study area. Assistance is being provided to four agencies who wish to use the mobile salinity assessment technology in their water quality protection programs.

CALIFORNIA A WATER DESELENIFICATION PROCESS USING ACCELERATED MICROBIAL VOLATILIZATION. W. T. Frankenberger, Jr., Univ of CA, Riverside. Report Period: 6/90 - 4/91. High levels of selenium in agricultural drainage water has promoted the need for immediate remediation of such waters. Studies are being implemented to utilize indigenous microorganisms existing in such waters. Optimization of both biological and environmental factors are key components in successfully combating this problem. We have successfully isolated bacterial isolates from such waters that have the ability to volatilize selenium and significantly reduce the selenium inventory. Acceleration of such a methylation process has been brought about by the use of well-aerated, well-mixed protein/cofactor-amended water. The scope of this project is to ultimately understand the biological process of selenium volatilization principally with respect to the genetics and the enzymological framework. It is the goal of this group to eventually provide a cost-effective system for the removal of selenium-contaminated water.

CALIFORNIA COMPARISON OF TRANSFER FUNCTION AND MECHANISTIC FLOW AND TRANSPORT MODELS. W. A. Jury, Z. J. Kabala, S. R. Yates, Univ of CA, Riverside. Rpt Period: 7/91 - 2/92. A two dimensional numerical water and chemical transport model was adapted to the set of problems covered under this project by generating a random grid of hydrologic and solute transport and retention functions to represent a heterogeneous unsaturated field. This random field was endowed with properties similar to those measured in real experiments. Using a supercomputer, we solved for water content and solute concentration values for the case of uniform water application to the soil surface. The output at a given depth below the surface is being averaged to represent various field sampling devices. Now that the numerical code has been developed, we are proceeding with the set of problems covered under our proposal, simulating conventional analysis of the transport problem and comparing it to predictions made using a transfer function model.

CALIFORNIA FIELD TEST OF A STOCHASTIC, ORGANIC SOLUTE, TRANSPORT MODEL. D. Rolston, L. Kavvas, J. Biggar, K. Scow and B. Hammock, Univ of CA, Davis. Report Period: 7/90 - 3/92. New stochastic methodology has led to analytical expressions for the one-dimensional, time-space varying probability density function for solute concentration under a nonstationary flow field. Characterization of soil and hydraulic parameters for the field are completed, and mean and covariance behavior of water flow were characterized from two soil-water drainage cycles. Comparison of theoretical and empirical (Monte-Carlo) probability density functions showed good agreement. A nonreactive tracer (chloride) has been applied to 24 subplots and a second application made to 8 of these. Mass fluxes varied greatly between the two applications. The chloride data are currently being used for validation of the stochastic methodology. Time domain reflectrometry (TDR) was evaluated as a rapid and inexpensive technology for measuring solute transport in soil. The movement of a chloride pulse through 45 cm of soil could effectively be monitored with TDR. Application of a reactive tracer (atrazine) is planned.

CALIFORNIA WATER QUALITY MODELS FOR IRRIGATED SALT-AFFECTED SOILS. M. Th. van Genuchten, J. D. Rhoades, S. R. Yates, D. L. Corwin, and W. F. Spencer, U. S. Salinity Laboratory, USDA-ARS, Riverside. Report Period: 5/90 - 2/92.

The purpose of this project is to develop numerical models for predicting the movement of water and dissolved constituents in irrigated salt-affected lands, and to use these models to develop

scenario's for achieving agricultural sustainability and salt balance for affected areas. An improved one-dimensional model (HYDRUS) has been developed for variably-saturated flow and chemical transport in and below the soil root zone. The model includes hysteresis in the soil hydraulic properties and nonlinear solute exchange between the soil solution and the solid phase of the soil. Version 1.1 of a two-dimensional finite element code (SWMS_2D) has also been released. The two-dimensional code considers water and solute movement in nonhomogeneous unsaturated, partially saturated, or fully saturated media. Both codes are available upon request. Results of this study should help in formulating improved management strategies that minimize the leaching of salts and potentially toxic substances to underlying groundwater systems.

CALIFORNIA, RHODE ISLAND & WASHINGTON DC ECONOMIC INCENTIVES TO REDUCE AGRICULTURAL POLLUTION. J. E. Wilen, C. L. Kling, University of California, Davis, D. Wichelns, University of Rhode Island, M. Weinberg, USDA-ERS, Washington, D.C. (former graduate student, UC Davis). Report Period: 6/90 - 2/92.

Economic incentives to improve water management and reduce agricultural pollution of water resources have been implemented in the San Joaquin Valley. Farmers have responded to higher prices for irrigation water with improvements in existing irrigation practices. Drought-induced reductions in water supply have hastened investment in water-conserving irrigation technology. Dynamic analysis of farm-level investment decisions suggests that economic incentives may also be useful to increase the rate of investment in irrigation technology. Efficiency properties and fiscal effects of economic incentive programs are examined in a regional simulation model. Additional district-level and regional incentive programs will be analyzed in 1992.

COLORADO ROOT ZONE WATER AND CHEMICAL TRANSPORT AS ALTERED BY FLOW PATHS, CROP ROOTING, AND MANAGEMENT. L. R. Ahuja, J. G. Benjamin, USDA-ARS, Fort Collins. Report Period: 4/91 - 2/92.

A pilot study of chemical leaching in crop row versus interrow areas started earlier was completed. There were two major findings: (1) In corn on a sandy loam soil, there was significantly less leaching of a surface-applied tracer chemical beneath crop rows than beneath interrows; and (2) overall leaching was less under soybean than under corn. A modeling study of macropores in a silty clay loam soil showed: (1) Appreciable fast-flow through macropore, occurred only at high rainfalls; (2) relatively greater amount of water flowed through macropores than that of chemicals; (3) more of a pesticide was transported than nitrate; and (4) soil evaporation increased the amount of chemicals entering the macropores. Macropores not open in the soil surface conducted very little of water or chemicals.

COLORADO EFFECT OF BEST MANAGEMENT PRACTICES ON GROUNDWATER QUALITY. D. S. Durnford, J. C. Loftis, L. R. Walker, Colorado State University. Report Period: 6/91 - 2/92.

The objectives of this study are to determine to what extent BMPs can reduce groundwater contamination and provide a method for predicting the effects of management practices on groundwater quality. Two study sites were chosen in the San Luis Valley that were adjacent but applied chemicals differently. The sites were characterized and both the shallow groundwater and the soil zone were monitored for nitrates and pesticides. From the preliminary analysis, it appears that the spatial variability of both the soil physical parameters and the chemical application rates is high. In addition, the preliminary data show some indications that the chemicals may move to the groundwater through preferential pathways. We will explore these possibilities in the next phase.

COLORADO WATER AND NITROGEN MANAGEMENT TO PROTECT GROUND-WATER QUALITY. R. F. Follett, M. J. Shaffer, L. K. Porter, A. R. Mosier, all USDA-ARS. Report Period: 1/90 - 2/92.

Nitrification Inhibitor: An inexpensive nitrification inhibitor was developed in Ft. Collins, a Patent Application accepted by ARS, extensive field tests conducted, the IFDC is investigating possible manufacturing processes. **User Friendly N-Management Principles:** Two books, a computer model, and a data base for the Midwest are published and Technology Transfer is being implemented. **NLEAP-GIS Technology:** Techniques have been developed to link the NLEAP computer model to GIS using the Sycamore Creek Watershed in MI for testing. Analyses indicate that nitrate

leaching "hot spots" occur within a watershed rather than across the entire landscape. The important fact for nitrate leached is the amount of residual nitrate in the soil profile. Irrigated Corn/Labeled Nitrogen Research: A depleted ^{15}N field study to determine effects of irrigation levels, fertilizer N-rates show a considerable time lag for transport of surface applied N through a 1.22m soil profile.

COLORADO WATER AND NITROGEN MANAGEMENT TO PROTECT GROUND WATER QUALITY. D. F. Heermann, R. F. Follett, M. Shaffer, H. R. Duke, E. E. Schweizer, USDA-ARS, Ft. Collins, CO. Report Period: 2/91 - 2/92.

An NLEAP-GIS application is in progress to identify nitrate-N leaching hot-spots and suggest management strategy alternatives across the Northern Colorado Water Conservancy District. A cooperative study with the NCWCD is providing soil land use, crop management, ground water and nitrate-N data suitable for model validation. The NLEAP model is identifying nitrate-N leaching problem areas. Nitrification inhibitors were used in irrigated corn and wheat field experiments. In corn, the nitrification inhibitors tested permitted only a small accumulation of nitrate in the root zone compared to that of the check treatment; a second year of wheat data is being collected. A literature search was completed for developing weed/crop models for managing weeds in barley and pinto beans. Data on the height and number of weed species in 15 corn fields were collected at harvest to estimate seed production and changes in weed seedbanks. Preliminary design of an irrigation system for chemigation studies and a review of the current chemigation technology was completed. Tifton, GA was visited to learn the details of their chemigation studies and the needs for future development.

COLORADO & UTAH CROP MANAGEMENT KNOWLEDGE BASED SYSTEM FOR REDUCING GROUNDWATER CONTAMINATION. J. Loftis, I. Broner, P. Soltanpour, K. Thompson, Colorado State University, and R. Peralta, R. H. Hanks, Utah State University. Report Period: 6/90 - 2/92.

A system is being developed for irrigated corn that will produce fertilizer recommendations and schedule irrigation to maintain yield while minimizing the potential for groundwater pollution by nitrates. A fertilizer module has been developed which uses BMPs, heuristic knowledge of soil fertility, and crop requirements to produce recommendations. An expert system shell has been embedded within the module to serve as an inference engine. An irrigation module will be developed, and both modules will be linked to a nitrate leaching model to minimize contamination potential. The USDA-ARS's NLEAP model will be incorporated to perform the nitrate leaching analysis.

COLORADO PREDICTING PESTICIDE LEACHING FROM SPATIAL VARIABILITY OF TRANSPORT PROPERTIES. J. C. Loftis, D. B. McWhorter, G. Butters, D. S. Durnford, Colorado State University, and H. R. Duke, R. F. Smith, USDA-ARS, Fort Collins, CO. Report Period: 6/90 - 2/92.

Three field studies of spatial variability of soil properties related to solute transport have been completed. The smallest-scale study (5m by 5m) dealt with transport of an adsorbed solute, atrazine under flood irrigation. Laboratory results are not yet complete. A larger-scale study (20m by 20m) evaluated spatial variability of soil moisture content and of median solute velocity using a bromide tracer under sprinkler irrigation. The largest-scale study (120m by 120m) considered steady-state infiltration rate as the variable of interest. Results of the third study have not yet been analyzed. However, geostatistical analysis of the measured variables in the second study indicate that the appropriate forms of statistical models to describe spatial variability are dependent on the spatial scale of interest. The remainder of the study will investigate the consequences of statistical model selection on statistical design of soil sampling programs for estimating means, percentiles, or proportions of random variables related to solute transport.

CONNECTICUT PREFERENTIAL FLOW OF ATRAZINE IN BANDED AND BROADCAST TREATMENTS IN CORN. K. Guillard, G. S. Warner, K. Hatfield, J. Stake, Univ of CT. Report Period: 6/91 - 2/92.

Installation of zero-tension pan lysimeters into a field to be planted to corn was completed during the growing season of 1991. A total of 48 lysimeters were installed. Thirty-two lysimeters (two under row areas, two under interrow areas; four replicates) were installed beneath undisturbed soil profiles in plots to receive either banded or broadcast applications of atrazine. In addition,

sixteen lysimeters (one under a row area, one under an interrow area; four replicates) were installed beneath disturbed soil profiles in each treatment. Lysimeter installation was completed too late in the growing season to seed corn and apply atrazine treatments. Water volumes are being obtained from each lysimeter after sufficient rainfall to assess the success of not functioning properly before treatment application in 1992. Preliminary soil cores have been taken from the field and procedures for the laboratory studies are being developed.

CONNECTICUT DEGRADATION OF PESTICIDE WASTES AND CONTAMINATED MEDIA. J. J. Pignatello. Report Period: 7/90 - 1/92.

A number of pesticides were treated with ferrous or ferric salts and hydrogen peroxide ($\text{Fe}/\text{H}_2\text{O}_2$), or the same in combination with UV/visible or UV light above 300 nm ($\text{Fe}/\text{H}_2\text{O}_2/\text{hv}$). In weak acid (optimum pH 2.8), $\text{Fe}/\text{H}_2\text{O}_2/\text{hv}$ treatment of herbicides 2,4-D and 2,4,5-T resulted in their rapid and complete mineralization to harmless inorganic forms, HCl and CO_2 , in less than 1 h. Only 5 moles peroxide per mole herbicide was required, indicating supplementary consumption of oxygen. Atrazine was dechlorinated but the atrazine ring remained intact. A number of Fe (III)-chelates were soluble and catalytically active in the dark at pH 6, giving 80% mineralization of 2,4-D and 2,4,5-T. Three chelates transformed atrazine, baygon, carbaryl, and picloram, but not trifluralin.

DELAWARE & MARYLAND NITRATE LEACHING FROM SOYBEANS AND SUBSEQUENT CONTAMINATION OF GROUNDWATER. J. J. Fuhrmann, B. L. Vasilas, University of Delaware, and J. S. Angle, University of Maryland. Report Period: 7/90 - 2/92.

Soybean and fescue control plots have been monitored in DE (loamy sand Coastal Plain soil) and MD (silt loam Piedmont soil) since Fall 1990. To date, there is no consistent evidence at either location of elevated nitrate levels in groundwater under soybeans as compared to the fescue controls. Soil samples collected at the MD location have shown higher concentrations of soil nitrate under soybeans than under fescue, but corresponding results for DE have been less consistent. Isotopic analysis of the DE soil taken from plant-free lysimeters amended with ^{15}N -labeled soybean residues indicated that mineralized N moved to the 90 to 120 cm depth within 6 months of harvest. In summary, despite instances of greater concentrations of soil nitrate under soybean than under fescue, there is as yet no consistent evidence that these nitrate levels are significantly impacting groundwater quality. However, the appearance of elevated ^{15}N -labeled nitrate concentrations at depths approaching the lower range of plant rooting suggests leaching may occur in the early Spring prior to significant plant root development.

DELAWARE LEACHING, SORPTION AND BIODEGRADATION OF HERBICIDES IN SUBSOILS OF A COASTAL PLAIN WATERSHED. J. T. Sims, J. J. Fuhrmann, and D. L. Sparks, University of Delaware, Newark. Report Period: 9/89 - 2/92.

Herbicide leaching and biodegradation experiments were conducted with soils from an Atlantic Coastal Plain watershed. Leaching of atrazine and metolachlor occurred more rapidly in a Klej loamy sand than in the Matawan sandy loam, likely due to the greater retention of these herbicides in subsoil horizons of the Matawan soil that were high in clay and Al/Fe oxides. The degradation potential of atrazine and metolachlor was studied with subsoil horizons from the Klej loamy sand, the Matawan sandy loam, and a Runclint loamy sand. Evolution of $^{14}\text{CO}_2$ was low ($< 1.6\%$), indicating that little mineralization of herbicides occurred in these subsoils. Methanol extracts from the soils receiving atrazine showed that between 89.5 and 91.6% of the extractable ^{14}C was present as the parent compound at the end of the experiment. Analysis of the methanol extracts of the metolachlor-treated soils indicated that 3 to 5% of the parent compound was subject to dechlorination. The results suggest that although certain coastal plain subsoils may have considerable potential to sorb herbicides, the mineralization potential of these compounds is low. Thus, herbicide that is leached to these subsoils may be sufficiently persistent to represent a long-term contamination threat to groundwater.

FLORIDA DEGRADATION OF TELONE II AND FENAMIPHOS IN SUBSOILS AND GROUNDWATER, AND BY MICROORGANISMS. L. -T. Ou, University of Florida. Report Period: 7/90 - 2/92.

Degradation rates of ¹⁴C-Telone in soil decreased with soil depth. Soil samples were collected from a Telone experimental site in Florida from surface to the top of watertables. Degradation rates of Telone in groundwater samples were low and were similar to the subsoil samples collected from the top of watertables. Fenamiphos in surface soil and shallow subsoil collected from a turfgrass site in Florida was rapidly degraded. This site has been treated with fenamiphos annually or biannually since early 1970. Half-lives for total toxic residue (fenamiphos + fenamiphos sulfoxide + fenamiphos sulfone) were very short, ranging from 0.9 to 4.2 days. Repeated applications of fenamiphos will not cause groundwater contamination.

GEORGIA CHEMIGATION IMPACTS ON WATER, SOIL, AND CROP QUALITY. J. E. Hook, J. G. Davis-Carter, and G. J. Gascho, University of Georgia and R. D. Wauchope, C. C. Dowler, A. W. Johnson, USDA-ARS, Tifton, GA. Report Period: 5/91 - 2/92.

A field comparison of chemigation versus conventional application of N and K fertilizer and atrazine, alachlor, and fenamiphos pesticides was monitored for nitrate and pesticides in soil water and shallow groundwater. Application of fertilizers through irrigation reduced nitrate leaching by spreading-out N applications. Less fertilizer was on the field at any time to be subject to leaching. Chemigation also allowed timely application of herbicides to the correct stage for weed control, when the soil was too wet for tractor traffic. Pesticides were found in soil water at 1.2 m within a few days after application by both methods. However, early results from this research suggest caution in recommending chemigation of pesticides which may move more readily in the freely draining fraction of soil water when preapplication soil water content is high.

GEORGIA WINTER COVER CROPS IN REDUCTION OF NO₃ LEACHING. J. W. Johnson, W. L. Hargrove, P. L. Raymer, University of Georgia, Tifton and J. E. Box, Jr. USDA-ARS, Watkinsville, GA. Report Period: 6/90 - 2/92.

The overall objectives of this research are to evaluate several winter annuals for rooting depth and residual N recovery and to compare winter cover crop and fallow for the amount of nitrate leaching over the winter months. We have two years of results from a preliminary evaluation of winter annuals for their adaptability as winter cover crops. These results show that canola, oats and forage turnips show promise as winter cover crops to prevent nitrate leaching. More detailed studies of rooting depth and N uptake for rye, canola, and crimson clover reveal that rye has the greatest amount of early growth and N uptake, but canola equals rye as the season progresses. Preliminary results from the tile drainage experiment indicate a rye cover crop significantly reduces the amount of water leaving the soil profile. Nitrate analyses are pending. The third year of the evaluation of the winter annuals and the second year of the extensive study of four selected winter annuals will be completed by June as planned. The third phase of the project on the influence of a cover crop on nitrate loss from tile drains has been initiated and will continue the next two years.

GEORGIA AGRICHEMICAL TRANSPORT AND CONTROLLING PROCESSES IN THE CLAIBORNE AQUIFER RECHARGE AREA OF SOUTHWEST GEORGIA. R. A. Leonard, D. D. Bosch, and C. C. Truman, USDA-ARS, Tifton, Georgia. Report Period: 2/91 - 2/92.

Atrazine, alachlor, and carbofuran pesticides applied in corn production on a Eustis soil near Plains, GA have been intensively studied since 1989 for their transport and transformation in the root zone, vadose zone and ground water. Studies also include chloride and bromide tracers and fertilizer nitrogen. Complete hydrologic, climatic, and cropping records have been maintained. Preliminary evaluation of models by the agencies involved (ARS, USGS, EPA) has been conducted. Little pesticide movement below about 3 m based on soil sampling has been observed. However, traces of pesticides and bromide appeared in ground water by the end of the second year. Studies on rates and pathways of atrazine degradation will continue to define the significance of hydroxyatrazine formation. Bromide data has shown a significant lateral transport vector in the vadose zone. A second plot area has been characterized by ground penetrating radar and future

studies will test this and other geophysical methods for non-destructive characterization of subsurface flow paths. Cooperative studies in other areas of the Claiborne Aquifer are being conducted with USGS to place the specific studies at Plains in regional perspective.

GEORGIA DEVELOP DECISION AIDS AND OTHER MODEL-BASED SYSTEMS FOR ENHANCING WATER QUALITY AND FARM PROFITABILITY. R. A. Leonard, D. D. Bosch, C. C. Truman, USDA-ARS, Tifton, Georgia. Report Period: 1/90-2/92.

In joint studies with D. B. Beasley, W. G. Knisel, and M. Smith of the University of Georgia, the GLEAMS model has been augmented to include a nitrogen and phosphorus component and animal waste as a nutrient source. Tillage, chemigation, crops, application methods, and other management-specific conditions were included as in the pesticides component. GLEAMS has been modified to improve the irrigation algorithms and options, adapt to forest conditions by changes in Leaf-Area Index and addition of canopy interception functions, and allow for in-puts of saturated hydraulic conductivity values by genetic soil horizon. Model application studies were conducted to evaluate effects of variable pesticide half-life with soil depth, evaluate risk assessments for regulatory purpose using "worst-case" single event pesticide runoff vs long-term annual means, evaluate applicability in representing management options, and to evaluate soil-pesticide vulnerability groupings. GLEAMS was linked with a finite element model for transport in the vadose zone and preliminary evaluations were made with data from the interagency project near Plains, GA. Model maintenance and user support was provided for GLEAMS.

GEORGIA USE OF A RE-ESTABLISHED RIPARIAN FOREST TO CONTROL WATER POLLUTION FROM A MANURE APPLICATION SITE. R. Lowrance, R. K. Hubbard, USDA-ARS, Tifton, GA. Report Period: 2/91 - 2/92.

Field studies have been established at both a wetland restoration site below a center pivot used to apply liquid manure and a mature riparian forest which will be used to examine the effects of forest harvesting on water quality and soil processes. At the mature forest, sediment concentrations in surface runoff were reduced by over an order of magnitude (3800 mg/L to 331 mg/L) after flow through the 50 m buffer system. The first sampling to simultaneously measure denitrification, microbial biomass, and root biomass in the mature forest was completed in February. Nitrate levels in shallow ground water are elevated at the stream channel in the restored wetland indicating that it is not yet an effective nitrate sink.

HAWAII APPLICATION OF FRACTAL GEOMETRY FOR ESTIMATING SOIL HYDRAULIC PARAMETERS. H. Chang, G. Uehara, G. Y. Tsuji, University of Hawaii. Report Period: 7/90 - 2/92.

A method has been developed to estimate the water content-pressure and hydraulic conductivity-water content curves from particle size distribution. The particle size distribution is a fractal distribution and obeys the power law. The slope of the power law in log-log plot is related to fractal dimension. The slope of the particle size distribution is in turn related to the slopes of the log-log plots of the water content-pressure and conductivity-water content curves. A computer software, called MESH (Method for Estimating Soil Hydraulic parameters), has been developed to enable users to compute and display water retention curves and conductivity-water content curves estimated from particle size data.

IDAHO MICROBIAL DETOXIFICATION OF PESTICIDE CONTAINERS AND RINSEATES. R. L. Crawford, D. L. Thill, H. W. Homan, University of Idaho. Report Period: 7/90 - 2/92.

A method using *immobilized microbial cells* for on-site detoxification of pesticide residues has been developed. A co-culture of the parathion degraders *Pseudomonas cepacia* and *Ps. dimunita*, entrapped in alginate and freeze-dried, had a survival rate (26 days, 20°C) of 103-105 cells/g beads. Immobilized and air-dried on kaolinite clay, the co-culture had a survival rate (33 days) of 105-107 cells/g. A *Ps.* sp. able to grow on 2,4-D was immobilized in alginate and freeze-dried, with good survival for 90 days. Optimal conditions for degradation of 2,4-D in Amine 4, Trimec, and Weedestroy by immobilized cells were 27-30°C and pH 7.3. Even after storage, both degraders degraded their target compounds in residues from used containers. Packets of freeze-dried microorganisms to treat rinseates and empty containers may eventually be produced,

eliminating hazardous residues at their source. This cheap, safe, and simple technology could greatly reduce pollution from the ~30 active ingredients found in 90% of pesticides used in the U.S., and should be widely adopted by pesticide users.

IDAHO APPLICATION OF GENETICALLY ENGINEERED MICROORGANISMS IN REMEDIATION OF CHLOROAROMATICS. C. S. Orser and R. L. Crawford, University of Idaho. Report Period: 8/91 - 2/92.

Several critical steps have been attained for the completion of the first objective of this research, which is the construction of a recombinant *Flavobacterium* strain with enhanced metabolic activity against chlorinated aromatics. First, a reproducible procedure for the transformation of *Flavobacterium* sp. strain ATCC 39723 is being developed for demonstration of homologous genetic recombination. Second, the primary gene of interest for genetic modification, *pcpB*, which encodes pentachlorophenol (PCP) hydroxylase has been characterized to the nucleotide level. Third, the enzymatic reactions catalyzed by PCP hydroxylase and its surprisingly diverse substrate range have been described in detail.

ILLINOIS HERBICIDE DISSIPATION AND WEED CONTROL MODELS FOR REDUCING HERBICIDE CONTAMINATION OF GROUNDWATER. M. G. Huck, L. M. Wax, USDA-ARS, Urbana, IL. Report Period: 4/90 - 2/92.

Field studies of changes in soil water content and root growth profiles provided an experimental basis for estimating water flow and root water uptake patterns for predicting the rate and direction of solute movement within the profile. Root pruning by corn rootworm feeding, or xylem flow restriction by *phytophthora* infection of soybean roots restricted water uptake activity to surface soil. Nitrogen fertilization stimulated vegetative proliferation of roots, promoting utilization of water reserves held in the subsoil under drought conditions. A general 2-dimensional computer model for flow through porous media was adapted to the GLYCIM model for soybean growth and tested against experimental measurement data; predictions of water movement were generally accurate on dry-down, but sizeable predictive errors following heavy rainfall or irrigations were noted, since macropore flow is not considered by the model at present. A decision-support model for corn and soybean herbicide selection using soil characteristics from the SCS national soils database is ready for beta-test installation in selected county field offices.

ILLINOIS & OHIO WATER FLOW AND HERBICIDE TRANSPORT THROUGH SOIL MACROPORES. F. W. Simmons, C. W. Boast, Univ. of IL & E. L. McCoy, Ohio State Univ. Rpt Period: 8/90 - 3/92.

Herbicide movement through earthworm channels is a suggested mechanism for transport of soil applied herbicides through the root zone. Precipitation history shortly after herbicide application may be important in determining delivery of herbicides in macropore or soil matrix flow. We tested the hypothesis that a light rain may move herbicides into the soil matrix thereby allowing cleaner bypass flow in subsequent rainfall events. Undisturbed 7.5-cm diameter soil cores containing a single continuous macropore were sampled from a Drummer silty clay loam. Four saturation level groups between 0.25 and 0.85 were surface sprayed with alachlor, metolachlor, and atrazine. Of the herbicide entrained in the macropore, 6-17% was sorbed to the 7.5-cm long macropore wall. Rainfall amount and rainfall history following herbicide application will have a strong effect on herbicide entry into macropores. The sorption and hydraulic environment of the macropore system will determine ultimate delivery through the solum.

ILLINOIS & NORTH DAKOTA EVALUATION OF NATURAL ABUNDANCE ^{15}N TECHNIQUES FOR GROUNDWATER NITRATE STUDIES. R. M. Vanden Heuvel, R. L. Mulvaney, Univ. of Illinois; L. Prunty, B. R. Montgomery, North Dakota State University. Report Period: 5/89 - 3/92.

The lysimeter study comparing labeled ^{15}N fertilizer and natural abundance ^{15}N fertilizer to evaluate $\delta^{15}\text{N}$ techniques for assessing the origin of NO_3^- in groundwater had been completed. There was a wide range of background $\delta^{15}\text{N}$ values found in the unlabeled lysimeters (-2.5 to +27.0). Results from the labeled lysimeters indicated that isotopic dilution was extensive (at least 24 fold). This range of background $\delta^{15}\text{N}$ values and the extensive isotopic dilution would make it impossible to use natural abundance techniques even in simple systems. An adjacent field study (64 ha) also indicated $\delta^{15}\text{N}$ techniques could not separate sources of nitrate.

ILLINOIS WEED MANAGEMENT AND APPLICATION TECHNIQUES FOR GROUNDWATER QUALITY PROTECTION. L. M. Wax, E. W. Stoller, J. W. Hummel, D. M. Alm, and M. D. Cahn, USDA-ARS, and L. E. Bode, University of Illinois. Report Period: 4/90 - 2/92.

The research here employs both experimentation and simulation modeling to reduce herbicide input and increase application efficiency. A computer model of emergence proved successful in the field; and mechanistic water relations models were developed for three important weeds. Laboratory and field studies showed that starch encapsulated herbicides may reduce leaching with little loss of herbicidal activity. Field experiments using less than 50 g/ha of postemergence herbicides showed that weed competitiveness can be reduced and the weeds can serve as a 'cover crop' for corn and soybean production. A machine vision sensor has been tested that processes two images simultaneously to guide herbicide applicators through the field. A computer model that includes air turbulence has been developed to predict the spray deposition in a plant canopy.

INDIANA & GEORGIA DECISION SUPPORT SYSTEMS FOR EVALUATING GROUNDWATER QUALITY PROBLEMS. B. A. Engel, Purdue University, D. B. Beasley, University of Georgia, K. M. Embleton, J. P. Gurganus, X. Zhuang, L. Rhykerd, D. D. Jones, Purdue University, M. C. Smith, W. G. Knisel, University of Georgia, R. A. Leonard, USDA-ARS, Tifton, GA. Report Period: 6/90 - 2/92.

A decision support system is being developed to identify existing and potential groundwater pollution problems, to identify the source(s) of pollution, and to suggest corrective or preventative measures. A structure has been developed for constructing the system. Modules that will become part of the decision support system are being developed (9 in development) with 8 modules complete. These modules provide risk assessment and information concerning management practices to prevent groundwater quality problems. They are useful by themselves but will become even more useful when integrated within the decision support system. Laboratory and field data are being collected at the University of Georgia for module development and testing. The GLEAMS model has undergone additional testing and development at the University of Georgia and Purdue University. GLEAMS did a reasonable job in estimating masses of pesticides moved through the root zone and the timing of their appearance in tile flows for 5 years of field data from southeast Indiana.

INDIANA FIELD SCALE PREFERENTIAL FLOW ON STRUCTURED AND NON-STRUCTURED SILT LOAM SOILS. E. J. Kladviko, R. F. Turco, G. E. VanScoyoc, J. D. Eigel, Purdue Univ. Report Period: 9/91 - 2/92.

Data on tracer and pesticide losses in a subsurface tile drain provided additional evidence for preferential flow of agricultural chemicals at the field scale. Bromide and simazine were detected in the first drainflow events after application, with less than 1 cm net drainage from the soil. Using a simple piston-flow model as the comparison, these data indicate that at least 7% of applied chemicals may be moving through preferential flow paths. Total mass losses of simazine during the first 8 cm of drainage were roughly predictable from the bromide data, suggesting that in some cases, tracers may be useful for predicting pesticide losses even with preferential flow and non-equilibrium conditions. Initial mass balance calculations for bromide suggest that the tile drain methodology as proposed, may provide sufficiently good field estimates of preferential flow for many purposes.

INDIANA CONTROLLED RELEASE HERBICIDE FORMULATIONS - THEIR EFFICACY AND ROLE REDUCING GROUNDWATER CONTAMINATION. M. M. Schreiber and M. V. Hickman, West Lafayette, IN, both USDA-ARS. Report Period: 1/90 - 2/92.

Experimental starch encapsulated (SE) formulations of atrazine, alachlor and metolachlor were field tested for efficacy in 1990 and 1991 at 10 sites in the midwest representing a wide range of soils and weed populations. SE formulations controlled foxtails, pigweed, lambsquarter, common ragweed, kochia and smartweed as well as commercial formulations. Control of crabgrass, velvetleaf and cocklebur were more site specific and variable with excellent to poor control. Corn yields from plots treated with SE formulations were statistically equal or better than those from

plot treated with commercial formulations. Laboratory and field experiments indicate that SE encapsulated atrazine is significantly less mobile and less likely to move preferentially under conventional, chisel and no-till systems than commercial formulations.

IOWA AVAILABILITY OF ORGANIC CARBON FOR DENITRIFICATION OF NITRATE IN SUBSOILS AND GROUNDWATERS. J. M. Bremner and G. W. McCarty, Iowa State Univ. Rpt Period: 9/89 - 2/92. Work performed showed that the slow rate of denitrification in Iowa subsoils is not due to a lack of denitrifying microorganisms, but to a lack of organic carbon (C) that can be utilized by these microorganisms for reduction of nitrate. Studies concerning movement of organic C from surface soils to subsoils showed that drainage water from tile drains under agricultural research plots contained only trace amounts of organic C and had very little, if any, effect on denitrification of nitrate in subsoils. Other studies showed that aqueous extracts of surface soils promoted denitrification in subsoils and that their ability to do so increased with increase in their organic C content. Amendment of surface soils with corn or soybean residues led to a marked increase in the organic C contents of aqueous extracts of the soils and in the ability of these extracts to promote denitrification in subsoils, but growth of corn, soybean, wheat, and sorghum plants on surface soils did not have similar effects.

IOWA ANALYTICAL DETECTION OF CHEMICALS IN THE SOIL AND GROUND WATER. J. L. Hatfield, and R. L. Pfeiffer, USDA-ARS. Report Period: 3/90 - 2/92. Water and soil samples were analyzed for atrazine, alachlor, metribuzin, and metolachlor herbicides and nitrate-nitrogen from samples collected throughout the MSEA sites. The samples processed were over 5000 soil and 7000 water extracts for the calendar year. Each sample was subjected to QA/QC protocols, and comparisons with the external laboratory showed excellent agreement among the laboratories. The data base for each site has been developed to catalog the data for the project and to incorporate all QA/QC information. Only minor changes are being made in the operating procedures to permit a more rapid analysis of priority samples.

IOWA DEVELOPMENT OF FARMING MANAGEMENT SYSTEMS TO IMPROVE WATER QUALITY. J. L. Hatfield, T. B. Moorman, and T. R. Steinheimer, all USDA-ARS. Report Period: 3/90 - 2/92. Measurements made on the water flow and temperature patterns within a ridge-tillage and chisel-plowed system showed that the placement of chemicals in the ridge would be subjected to different leaching patterns in the ridge system. Nitrogen management systems need to be developed which account for realistic rather than overly optimistic yield goals and the soil survey reports could be used to develop yield goals. Placement of the chemicals within the upper soil profile and the distribution of these materials after a rainfall and throughout a growing season provide an understanding of the limits to which the system can be modified. These response characteristics are being studied with continued experimentation.

IOWA EVALUATION OF THE IMPACT OF CURRENT AND EMERGING FARMING SYSTEMS ON WATER QUALITY. J. L. Hatfield, USDA-ARS, Ames, IA, J. L. Baker, Iowa State University, and P. J. Soenksen, USGS, Iowa City, IA, **MSEA Project.** Report Period: 3/90 - 2/92. Field studies continued at all of the Iowa sites and the instrumentation was completed at each site to permit a complete array of observations. Herbicide concentrations in surface runoff showed high values during peak flow, and farming practices which reduced runoff also reduced pesticide movement. Concentrations of herbicides in tile drainage water were higher in the spring and early summer and modifications in application rates or times could improve the quality within the tile drain. Efforts are being made to assemble a complete data base for all of the parameters collected in the project and to relate these to landscape changes in water quality. A GIS approach to combine the observations and simulation models is being completed.

IOWA TRANSPORT AND CHEMICAL TRANSFORMATION OF PESTICIDES IN AGRICULTURAL SYSTEMS. J. L. Hatfield, T. B. Moorman, and T. R. Steinheimer, USDA-ARS, Ames, IA. Report Period: 2/90 - 2/92. Concentrations of atrazine, metolachlor, and metribuzin residues were measured in soil profile samples from Walnut Creek and Treynor watersheds. Atrazine and the metabolites desethyl- and

desisopropyl-atrazine (DEA and DIA) were detected in lysimeter and tile flow samples under no-till corn. Concentrations of DEA were generally greater than DIA. Other laboratory experiments were begun to examine the kinetics and pathways of alachlor degradation in soils, aquifer samples and microbial cultures. A screening experiment showed that the ability to degrade alachlor is widespread among soil fungi. Further studies will determine the factors limiting the activity of these isolates.

IOWA DECISION AID SYSTEMS FOR FARMING MANAGEMENT AND WATER QUALITY. D. B. Jaynes, J. L. Hatfield, and S. D. Logsdon, USDA-ARS. Report Period: 8/90 - 2/92.

Ponded and tension infiltration measurements indicated surface seal effects due to residue placement differences under different tillage systems. No-till had more rapid ponded infiltration than moldboard and chisel after heavy spring rains. Differences related to crop rotation and landscape position were not clear cut. Infiltration at water pressure heads of -3 and -6 cm increased over the season. Vertical worm channels below 55 cm depth resulted in faster vertical saturated conductivity relative to horizontal on a Kenyon Loam. Large surface cracks also contributed to rapid infiltration under ponded conditions. A post-doctoral position was filled to develop models of water and chemical transport through macropores.

IOWA IMPACT OF PREFERENTIAL FLOW ON CHEMICAL AND WATER MOVEMENT IN AGRICULTURAL SYSTEMS. D. B. Jaynes, S. D. Logsdon, and J. L. Hatfield, USDA-ARS. Rpt Period: 8/90 - 2/92.

In situ ponded and tension infiltration measurements were made at the three MSEA sites in Iowa at surface and near surface depths. The measurements were used to characterize different tillage systems, crop rotations, and landscape positions over time. Deep soil cores were taken at the Treynor deep loess site to measure the distribution of nitrogen, pesticides, and microbial activity with depth. Results from a chemigation study of a surface irrigated field showed that nitrate application in the irrigation water causes significantly greater leaching losses as compared to surface spray application prior to the irrigation (increased preferential flow).

IOWA GROUNDWATER RECHARGE AND CHEMICAL TRANSPORT IN TWO GLACIAL TILL CONFINING UNITS IN IOWA. R. S. Kanwar, W. W. Simpkins, R. O. Horton, T. E. Fenton, L. C. Jones, J. L. Baker, Iowa State Univ and G. R. Halberg, Iowa Dept of Nat Res, Iowa City, IA. Rpt Period: 7/90 - 2/92.

A large vertical borehole cavity (3.15 m in diameter by 3.3 m deep) and a system of lateral suction lysimeters has been installed at the Ames site. The system has been used to collect water samples from the saturated and unsaturated portions of the soil profile. Rainfall events and rainfall simulation events will be used to gain an understanding of chemical transport by preferential and unsaturated flow in the vadose zone. Water quality data from monitoring piezometers located throughout the field indicate pesticide concentrations below the detection limit and nitrate-nitrogen concentrations of less than 1 mg/l below a depth of 4.5 m. Data on subsurface drainage water indicate that split N-fertilizer application reduces NO₃-N concentration in the tile effluent.

KENTUCKY IMPACT OF RIPARIAN VEGETATION ON WATER QUALITY: MODELING AND MEASUREMENT. B. J. Barfield, R. Blevins, V. P. Evangelou, D. I. Carey, A. W. Fogle, University of Kentucky, Lexington, KY. Report Period: 5/1/90 - 2/1/92.

Field studies on water quality impacts of natural riparian vegetation have been completed as planned with laboratory analysis of samples nearing completion. Two remaining tasks are: 1. complete the models of sedimentation in natural grass vegetation, accounting for the effects of channelization and 2. complete the model of trapping of atrazine and phosphorous in natural vegetative filter strips (VFS). Strips of 15, 30 and 45 ft were established in naturally occurring riparian fescue where microchannels were likely to develop. Their effectiveness in trapping sediment, atrazine, phosphorous and nitrogen was evaluated. Results for tests analyzed to date show high trapping percentages.

KENTUCKY THE ROLE OF SEDIMENT IN NUTRIENT TRANSPORT IN A KARST GROUND WATER CATCHMENT. G. K. Felton, W. W. Frye, University of Kentucky. Report Period: 7/91 - 1/92. Field installation is proceeding according to schedule with the exception of obtaining land owner permission for one surface water sampling site. An alternate site is being investigated. Storm event sampling and analysis (4 hr sampling interval) at Owen's karst window and Garrett's spring was initiated with a storm on 8/28/91. The results were presented at the 1991 Annual Winter meeting of the ASAE. The most pertinent results based on three low flow events are: 1) nitrate concentration in the spring drops in response to precipitation, 2) calcium mass flow rate responds non-linearly with time resulting in a relationship that may aid hydrograph separation work, 3) flow through the karst conduit system resulted in increased nitrate concentration at the spring, and 4) flow through the karst system resulted in reduced solids, indicating deposition and storage were occurring in the underground conduit system. In general, during low flow events, the karst conduit system stores solids and releases stored chemicals.

LOUISIANA PERCEPTIONS OF WATER QUALITY PROBLEMS AMONG RURAL RESIDENTS OF THE SOUTHWEST LOUISIANA IRRIGATED RICE PRODUCTION REGION. E. J. Luzar and G. W. Wilkerson, Louisiana State University. Report Period: 5/90 - 2/92. Well data incorporated in a geographic information system for the Chicot Aquifer in Southwest Louisiana for use in economic and spatial analysis include agricultural use for irrigation, rural domestic use, and agricultural use for aquaculture. In addition to ground water problems related to chloride (salt-water) intrusion in the Chicot Aquifer region, presence of excessive suspended solids was identified as a primary surface water quality problem. As a result, water quality data from regional surface water monitoring stations were also entered into the GIS database for temporal and spatial analysis. Tasks which remain include administration and analysis of the attitudinal main surveys and estimation of willingness-to-pay values for changes in water quality.

LOUISIANA ATRAZINE IN THE SOIL ROOT ZONE AND QUALITY OF GROUNDWATER OF SHALLOW WATER-TABLE SOILS. H. M. Selim, D. C. Johnson, and L. Ma, Louisiana State University Agricultural Center and L. M. Southwick, G. H. Willis, USDA-ARS. Report Period: 8/90 - 2/92. The objective of this study is to quantify the mobility of atrazine in clay soils with a shallow water table. Sugarcane plots on Sharkey soil with drains with spacings of 6 and 12 m were used. All drains are located at 1 m depth below the soil surface. Atrazine was applied in June followed by another application in December (1990). Results following the June application showed a sharp rise in effluent concentration followed by a slow decrease for a period of two months. Maximum effluent atrazine concentrations associated with June application were 82 and 403 ppb for the 6 and 12 m spacing, respectively. Maximum concentrations associated with the winter application were 165 and 82 ppb, respectively. Atrazine applications were made in June and December 1991 and mobility of atrazine was monitored using solution samplers and drain outflow. Transport experiments were conducted on columns of Sharkey soil using ¹⁴C-labeled atrazine. Several aggregate size fractions were used to investigate the prediction capability of multi-domain solute transport models.

LOUISIANA WATER MANAGEMENT FOR IMPROVED GROUNDWATER QUALITY AND FARM CHEMICAL USE EFFICIENCY. G. H. Willis, J. L. Fouss, J. S. Rogers, C. E. Carter, L. M. Southwick, USDA-ARS, Baton Rouge, LA. Report Period: 1/89 - 2/92. The construction/installation of 16 watertable control plots will be completed in summer of 1992. Application of 4 watertable management variables will be initiated in the fall of 1992, and measurements of their effects on agrochemical transport in surface runoff and infiltrated water will begin with the 1993 cropping season. Development of water management strategies (models for automated subdrainage and subirrigation in relation to agrochemical application schedules) for using watertable control to improve water quality and farm chemical use efficiency will begin with the collection of the first year's data.

MAINE & NEW HAMPSHIRE IMPACTS OF PRECOMMERCIAL THINNING AND FERTILIZATION ON WATER QUALITY. R. D. Briggs, University of Maine, J. W. Hornbeck, USDA Foreign Service, C. T. Smith, University of New Hampshire. Report Period: 5/91 - 2/92.

Twenty-seven 10 m X 10 m plots, distributed over three soil drainage classes, were installed in dense areas of spruce-fir regeneration. Three treatments were randomly assigned (control, precommercial thinning (PCT), and PCT plus fertilization). Ceramic cup soil solution samplers were installed at 25 and 50 cm below soil surface, except for poorly drained plots where solum thickness limited installation to the 25 cm depth. Seven wells (depth ranging from 2.3-8.5 m below soil surface) were installed over the watershed. Height and diameter of trees on each plot were measured, crop trees were identified, and PCT treatments were applied. Solution samples were obtained from 45 lysimeters, 7 wells, and 6 stream sampling points in September and October 1991. Wells and streams were sampled again in November 1991 and January 1992. Monthly sampling for the 1992 growing season will begin April, 1992.

MARYLAND USDA-ARS PESTICIDE PROPERTIES DATABASE. B. Acock and P. Laster, Systems Research Laboratory and A. E. Herner, Environmental Chemistry Laboratory, ARS, NRI, Beltsville. Report Period: 1/91 - 3/92.

The ARS Pesticide Properties Database (PPD) is a compendium of chemical and physical properties of widely used pesticides. To the original 92 compounds in the database, about 140 compounds, as well as added data on the original 92, have been added from the SCS/ARS/SEC Database (D. Wauchope, ARS, Tifton, GA). We have focused on 19 of the most important properties impacting groundwater and atmospheric quality. In cooperation with the National Agricultural Chemicals Association (NACA) we have been provided with manufacturers original experimental data. This provides the basis for the PPD, which is augmented with data from the scientific literature and handbooks. All data points are referenced and the references are characterized.

MARYLAND PREDICTION OF GROUNDWATER CONTAMINATION FROM GENETICALLY ENGINEERED MICROBES. J. S. Angle, R. L. Hill, University of Maryland. Report Period: 6/90 - 2/92.

Leaching of genetically engineered microbes through soil is a significant concern related to groundwater quality. The purpose of this study was to examine the leaching, survival, and gene transfer of a genetically engineered microbe in an undisturbed soil column. Pseudomonas aeruginosa PA025, containing the plasmid R68.45, was added to the surface of undisturbed soil columns and the columns leached with water. Leachate was analyzed daily for the presence of donor and transconjugants. No donor or transconjugants were detected in the leachate at any time period. Periodically, cores were dismantled and sectioned by depth. After a slight increase, the donor population in soil decreased by both depth and time. Low numbers of transconjugants were present and also decreased with depth and time. These results show the importance of examining leaching and survival of both donor and transconjugant populations in soil.

MARYLAND DEGRADATION OF PESTICIDE WASTE BY OZONE AND MICROBIAL METABOLISM. C. J. Hapeman-Somich, D. R. Shelton, USDA-ARS, Beltsville, MD. Report Period: 7/90 - 2/92.

An urgent need exists for safe, cost effective technologies to dispose of pesticide wastes, including unusable rinsates, spills, outdated or cancelled stocks, and contaminated soils. A binary system, involving chemical pretreatment (ozonation) and microbial mineralization, has shown promise in laboratory and field tests. Development and optimization studies have focused on the recalcitrant s-triazine herbicides. The chemical degradation pathway has been elucidated and a microorganism isolated that is capable of mineralizing the products under simulated field conditions. Based on these results, a more efficient unit, amenable to a variety of chemical and microbial treatment strategies, has been fabricated.

MARYLAND MINIMIZING THE EFFECT OF MACROPORE FLOW ON PESTICIDE LEACHING. A. R. Isensee, A. M. Sadeghi, T. J. Gish, W. J. Rawls, USDA-ARS. Report Period: 1/91 - 2/92.

Effect of pesticides applied to the surface of no-till (NT) and conventional-till (CT) fields on pesticide leaching was evaluated. Results indicated that if rain occurs soon after application, that much more leaching (through macropores) to shallow groundwater (<3 m depth) occurs under NT than CT. A laboratory experiment conducted to evaluate the impact of earthworms on macropore

formation and water infiltration indicated that most of the water flow occurred through only a few of the worm holes. An apparatus to measure leaching through intact soil cores was constructed and evaluated. The apparatus can be used to rapidly evaluate soil-water-pesticide interactions as they affect pesticide leaching.

MARYLAND SPATIAL AND TEMPORAL DISTRIBUTION OF AIRBORNE ORGANIC CONTAMINANTS IN WET AND DRY DEPOSITION. W. E. Johnson and C. S. Schomburg, USDA-ARS, Beltsville, MD. Report Period: 3/91 - 3/92.

Pesticide partitioning between air/water and water/water-dissolved organic material (DOM) was investigated. DOM decreased extraction efficiency of several pesticides from water but the effect was pesticide dependent. Air/water partition coefficients for pesticides in water samples containing DOM are in some cases an order-of-magnitude lower than values in pure water, indicating an aqueous phase enrichment. Photolysis of several pesticides in laboratory solutions containing nitrate ion or estuarine river water indicated that nitrate enhances the rate of photolysis of alachlor and chlorpyrifos. Chlorpyrifos rapidly photodegraded in estuarine river water, while alachlor did not.

MARYLAND & IDAHO NUTRIENT MANAGEMENT EXPERT SYSTEM. H. Lemmon, B. Acock, USDA-ARS, Beltsville, and J. Bartulovitch, University of Idaho. Report Period: 2/91 - 2/92.

NUMEX is an expert nutrient management system for use in soil testing laboratories. It accumulates data on the nutrient content of soil samples submitted by farmers for analysis, and on the manure and sludge available for field application. Recommendations are then made to the farmer for fertilizer, manure and sludge application. The principal objective is to feed the crop while preventing the build-up of heavy metals in the soil, and preventing the contamination of surface and ground water, especially by nitrates. NUMEX was developed originally for the University of Maryland, and this project is to adapt it for use in the mid-West. Collaboration has been established with Drs. Voss and Killorn, Iowa State University, and Drs. Schepers and Frank, University of Nebraska. The rules for the original NUMEX have been examined by the collaborators for applicability in their state, and modifications and new rules proposed. Information on hardware availability and requirements for data input and output have been recorded. Coding of the expert system will follow.

MARYLAND EFFECT OF N PLACEMENT AND RIDGE TILLAGE ON NITRATE LEACHING AS TRACED BY BROMIDE. R. R. Weil and A. Shirmohammadi. Univ of MD, College Park. Rpt Per: 7/91 - 1/92.

Using established no-till (NT) or ridge-till (RT) corn plots in a corn/soybean rotation, we installed three grids of tensiometers, each with 5 banks of 6 instruments set from 15 to 90 cm deep. We installed two similar grids of 30 suction lysimeters each, 1.5 m on both sides of each tensiometer grid. Lysimeters were made of 1.2 cm ID PVC with a porous ceramic tip and sample access and vacuum tubes. Tensiometers were fitted with a rubber septum cap for use with a transducer-equipped 'tensimeter'. Some soil water samples were obtained beginning in August, but due to extremely dry conditions, complete sets were not obtainable until November. Ion chromatograph peaks for Br⁻¹ and NO₃⁻¹ ions partially overlapped, but were sufficiently separated to obtain good standard curves using values for peak heights rather than peak areas. Preliminary data shows some horizontal trends in Br⁻¹ and NO₃⁻¹ concentrations, but a high degree of spatial variability in all systems. Concentrations of Br⁻¹ and NO₃⁻¹ were highly correlated ($r=.88$). Determination of Br⁻¹ and NO₃⁻¹ in lysimeter and soil core samples is currently underway and a leaching study is being set up using a mechanical vacuum extractor to determine the anion and cation exchange properties of the soils and compare the adsorptive behavior of the Br⁻¹ and NO₃⁻¹ anions.

MASSACHUSETTS & CONNECTICUT REGULATIONS AND ECONOMIC INCENTIVES FOR ACHIEVING GROUNDWATER QUALITY. C. R. Harper, C. E. Willis, J. T. Finn, University of Massachusetts, K. Segerson, University of Connecticut. Report Period: 7/91 - 2/92.

Major sources of groundwater contamination in a mixed land use setting are being investigated along with possible policy remedies. Land use data for southern New England have been developed in a Geographical Information System (GIS) format and are being refined to a crop-specific level.

Data on site characteristics, including soils, are in progress. To model economic responses to taxes and other incentives, a regional supply and demand model for major crops and agricultural inputs is being developed. When completed, the combined physical and socioeconomic models will permit comparisons of the costs and effectiveness of alternative protection policies.

MASSACHUSETTS DAIRY MANURE ON ALFALFA TO REDUCE OVERAPPLICATION AND N LOSS FROM CORN FIELDS. S. J. Herbert, J. Daliparthi, P. L. M. Veneman and J. Moffitt, University of Massachusetts. Report Period: 6/90 - 2/92.

Applying dairy manure to alfalfa as an alternative to excess application to corn can reduce nitrate pollution of ground water. Water samples collected in suction lysimeters at 30, 60, 90 and 120 cm depth at two sites had significant amounts of $\text{NO}_3\text{-N}$. Covariance was high among treatments, sampling depths and the sampling dates. There was no difference in $\text{NO}_3\text{-N}$ concentrations in leachate from low (112 kg N ha⁻¹) manure and control plots, whereas high (336 kg N ha⁻¹) fertilizer and high manure (2nd year) showed significantly more $\text{NO}_3\text{-N}$ in leachate than the control. Manure application to alfalfa neither reduced forage yield nor increased weeds. More research is needed on leachate through macropores and residual effects of manure on long-term nitrate leaching. These preliminary results indicate farmers could apply manure to alfalfa at rates of 20 to 30 ton/acre without an adverse effect on ground water quality and without economic risk.

MICHIGAN, PENNSYLVANIA & MINNESOTA ASSESSMENT AND MODELING OF NITRATE LEACHING UNDER CONVENTIONAL AND ORGANICALLY MANAGED CORN. E. A. Paul, P. Grace, G. H. Harris, O. B. Hesterman, J. T. Ritchie, K. Paustian, Michigan State University, S. E. Peters, R. R. Janke, K. Kroll, Rodale Inst, J. A. E. Molina, Univ of Minnesota. Report Period: 7/90 - 2/92.

Natural drainage lysimeters were installed in a long-term cropping system experiment at the Rodale site in October 1990. Nitrate-N leached from animal-, legume green manure- and fertilizer-based cropping systems for October 1990 to May 1991 measured 22, 15 and 11 kg ha⁻¹, respectively. Loss of N by nitrate leaching was also highest in the animal-based system from May-October 1991, but was relatively low for all three cropping systems. Results suggest that the method of manure application used in this study needs reevaluating and nitrate leaching may not be the main mechanism of N loss at this site.

MICHIGAN & KANSAS STRATIFICATION AND FATE OF N WITHIN SOIL PROFILES: MANAGEMENT-INDUCED CHANGES. F. J. Pierce, J. R. Crum, B. D. Knezek, Michigan State University and C. W. Rice, M. D. Ransom, and R. E. Lamond, Kansas State University. Report Period: 4/90 - 3/91.

Drought and adequate rainfall years occurred in alternating years at Michigan and Kansas. Corn responded to N applications only in the dry year at Kansas and the adequate rainfall year at Michigan. No $\text{NO}_3\text{-N}$ leaching occurred at Kansas, but high solution concentrations ($> 50 \text{ ug m}^{-1}$) were measured at Michigan during the non-crop period, with higher concentrations in soybeans than corn and in ridge-till than other tillage systems. Manure increased denitrification potential by 6 times over fertilized treatments and increased soluble C at depth in Kansas. Tracer studies this year will quantify effects at stratification, row position, and preferential flow.

MINNESOTA A FIELD TRACER TEST METHOD FOR LARGE SOIL SAMPLES. E. C. Alexander, Jr., J. L. Nieber, University of Minnesota. Report Period: 6/91 - 2/92.

Large diameter tree transplanting equipment is being tested for use in a new method of measuring flow in the unsaturated zone. Tree transplanting equipment is widely available and in minutes can excavate a two cubic meter volume soil sample without obvious soil disturbance. The method entails the temporary excavation of a soil sample using the tree transplanter then returning the sample to the same hole after the installation of a sump and a funnel shaped impermeable liner. Tracer tests can then be carried out by applying water at the surface, and sampling from the sump using an automatic sampler. This methodology generates discharge-time-solute concentration data on a one minute time interval and is therefore ideal for studying rapid flow processes through soils. The experimental isolation of equipment effects, and a full analysis of soil sample

disturbance in a variety of soils are major goals of the remainder of this project. The method has the potential to be a rapid, practical and cost effective means of measuring both porous-media and preferential flow effects in the unsaturated zone.

MINNESOTA, WISCONSIN, N DAKOTA & S DAKOTA NORTHERN CORNBELT SAND PLAINS

MSEA. J. L. Anderson, University of Minnesota; R. H. Dowdy, USDA-ARS, St. Paul, MN; and G. N. Delin USGS, St. Paul, MN, **MSEA Project.** Report Period: 7/90 - 2/92.

Field experiments were established at one main location (Princeton, MN) and three satellite sites (Oakes, ND; Aurora, SD; and Arena, WI) in 1991. Initial soil and aquifer characterization data were collected. The common farming system at all locations is a corn-soybean rotation using ridge tillage, band application of atrazine/metolachlor and alachlor, split N application, and irrigation scheduling. Two additional systems were established at Princeton, continuous corn and potato-sweet corn rotation. Continuous corn has full width tillage, broadcast application of atrazine and alachlor, split N application, and excess irrigation water. Potato production has full width tillage, broadcast application of metribuzin and metolachlor, split N application, and irrigation scheduling. Sweet corn is managed similar to corn in the corn-soybean rotation. The N application amounts for 1991 were 224 kg N/ha for potato, 156 kg N/ha for corn, and 0 kg N/ha for soybean. Forty-four water monitoring wells were installed and sampled for pesticides, nitrate, and water level. Soil spatial variability is being evaluated by both soil survey and grid sampling of crop yields in each area.

MINNESOTA DEVELOP ALFALFA TO INCREASE N₂ FIXATION AND REDUCE NITROGEN LOSSES TO THE ENVIRONMENT. D. K. Barnes, M. P. Russelle, J. F. Lamb, and C. P. Vance, USDA-ARS, St. Paul, MN. Report Period: 2/91 - 2/92.

Plans and facilities for this new project were developed and a new plant geneticist/plant physiologist hired. Experiments were initiated to: 1. Evaluate the dynamics of root growth and senescence utilizing minirhizotron methodologies; 2. compare rate and depth of soil nitrate removal by effectively and ineffectively nodulated plants grown on an abandoned manure application study having varying amounts of subsoil nitrates (about 280 to 2800 kg N/ha); 3. evaluate yield and BNF of alfalfa germplasms selected for NO₃ reductase and nodule effectiveness when fertilized with ammonium nitrate; 4. evaluate the effects of bidirectional selection for alfalfa nodule enzymes, nodule fresh weight, nodule soluble protein concentration; and shoot dry weight; and 5. breed special purpose alfalfas that can be used to improve energy efficiency of crops grown in rotation, to improve N cycling when manures are applied and to remove nitrate from below the root zone of cereal crops.

MINNESOTA EFFECTS OF SOIL FREEZING ON THE FATE OF SOIL APPLIED NITROGEN AND PESTICIDES. G. R. Benoit, J. A. Daniel, J. A. Staricka, USDA-ARS, Morris, MN. Report Period: 1/90 - 2/92.

A two phase field study continues to evaluate frost-landscape effects on winter movement of nitrate and atrazine to surface and ground water. In phase one, data from a grid of 15 groundwater observation wells and an instrumented leg of a transect through a field depression has shown lateral flow of water to the depression and rapid development of a groundwater recharge mound under the depression during runoff from thawing soil events. In phase two (located in depression 2), data from 4 tillage residue systems, each split with two levels of nitrogen and atrazine show frost induced soil water movement plus both lateral and vertical movement of nitrate and atrazine.

MINNESOTA SORPTION-DESORPTION PROCESSES AFFECTING PESTICIDE MOBILITY IN TILLED SOILS. C. E. Clapp, R. R. Allmaras, D. R. Linden, W. C. Koskinen, J. M. Baker, R. H. Dowdy, USDA-ARS, St. Paul, MN. Report Period: 7/90 - 2/92.

Tillage and methods of incorporating agrichemicals can significantly influence the escape of agrichemicals from their target position. The depth for incorporation of agrichemicals is predictable, but research now reveals how tillage and crop residues can influence the local environment of the incorporated agrichemical. A study was conducted to determine the effect of surface microrelief, microlandscape position, and rainfall intensity on water and solute transport in burrows created by earthworms. Models designed to predict flow in burrows must consider quantity of water available to, and flow within, a burrow. In laboratory experiments, desorption

coefficients were dependent on adsorbed atrazine concentration. For field-aged residues, desorption (K_1) values increased slightly with time. However, values were lower than would be predicted if based on laboratory data where equal adsorbed concentrations were compared. It is necessary to take into account the change in the atrazine-soil interactions with aging.

MINNESOTA WEED EMERGENCE MODELING FOR A WEED/CROP BIOECONOMIC EXPERT SYSTEM. F. Forcella, G. R. Benoit, USDA-ARS. Report Period: 1/90 - 2/92.

The Weed/Crop Bioeconomic Management Expert System, known as WEEDSIM, is being developed for the U.S. Corn Belt by a large team of economists and scientists from USDA and state experiment stations. WEEDSIM provides a basis for rational weed management decisions, and its use typically results in lower herbicide use in both corn and soybean crops. For the expert system to function properly, the timing and extent of weed seedling emergence in spring and early summer must be predicted. Simple and user-friendly computer models that make such predictions accurately have been developed for five important Corn Belt weed species. Models for other important weeds currently are in progress.

MINNESOTA & IOWA ROLE OF EARTHWORM MACROPORES IN PREFERENTIAL FLOW OF WATER AND CONTAMINANTS. S. C. Gupta, J. F. Moncrief, E. Munyankusi, A. Bhattacharjee, University of Minnesota, and É. C. Berry, USDA-ARS, Ames, IA. Report Period: 9/91 - 2/92.

Experiments are in progress to quantify the effects of nitrogen source on the distribution and continuity of soil macropores formed by earthworms. Six undisturbed cores (30 cm dia. by 100cm long) were taken from a field experiment with a continuous eight year history of inorganic N fertilizer or liquid dairy manure application. Earthworms collected at the time of core excavation showed that *Aporrectodea tuberculata* is present in the inorganic fertilizer plot whereas *A. tuberculata*, *A. trapezoides*, *Lumbricus rubellus*, and *L. terrestris* are present in the plot that received liquid dairy manure. Cores are being used to characterize water flux, macropore number, size distributions and continuity both by running breakthrough curves, paint injection techniques and image tracing of visible macropores at various depths. Image traces are being used to reconstruct cores on a computer screen to visually assess the continuity of macropores. Data will be analyzed with respect to the differences in earthworm specie on macropore continuity.

MINNESOTA & NEBRASKA INTEGRATION OF N MANAGEMENT ALTERNATIVES TO MINIMIZE GROUNDWATER CONTAMINATION. G. Malzer, P. Robert, D. Baker, J. Moncrief, R. Levins, University of Minnesota. G. Hergert, D. Martin, D. Watts, University of Nebraska, J. Schepers, USDA-ARS, Lincoln, NE, and R. Beck Cenex/Land-O-Lakes, St. Paul. Rpt Period: 8/89 - 2/92.

Expert systems are being developed within each state that would allow for site specific N fertilizer recommendations that are economically and environmentally sound. Teams from Minnesota and Nebraska have met on a regular basis to coordinate activities and to define conditions for site specificity, economic and environmental concern, and economic and logistical feasibility. Prototype expert systems have been developed and are currently being evaluated. The expert systems will utilize either soil information provided by the user, or will access site specific information from a digitized soil map and associated soil survey information. The latter feature will allow easy adaptability for variable N rates on-the-go. The site specific soil information is used along with user management information to determine the minimum rate of fertilizer N needed for production. Both components are integrated together to provide management recommendations that will minimize N loss during the growing season.

MINNESOTA ISOPOTENTIAL ION EXTRACTION OF PESTICIDES. A. Olness, N. T. Basta, USDA-ARS, Morris, MN. Report Period: 1/90 - 2/92.

US Patent 4, 816,161 was successfully modified using teflon components and XAD-2 resin for routine extraction of pesticides from soil suspensions and solutions. Extractions were effected over a broad range of soil types and environmental conditions. The extractor is capable of simultaneously extracting atrazine, metribuzin, and alachlor. An accurate and precise method has been developed which permits inexpensive extraction of large numbers of samples. Extractor eluates are injected directly into GC systems without costly cleanup procedures. Initial results

show similar pesticide recoveries under both aerobic and anaerobic conditions. Detection limits are 1 to 5 ng g⁻¹. Extraction conditions ($\geq 25^{\circ}\text{C}$ in 20% methanol) inhibit microbial decay and speed extractions.

MINNESOTA, IOWA & WISCONSIN REGIONAL ASSESSMENT OF SOIL NITROGEN TESTS IN IOWA, MINNESOTA, AND WISCONSIN. G. W. Randall, M. A. Schmitt, University of Minnesota, R. J. Killorn, R. Horton, M. Duffy, Iowa State University, and L. G. Bundy, P. Nowak, University of Wisconsin. Report Period: 5/91 - 2/92.

Thirty five field studies were conducted to assess soil N tests over a wide range of soil/climatic/crop conditions. Thirteen sites did not respond to fertilizer N. The pre sidedress soil nitrate test (0-1' sample) did not differentiate between responsive (R) and non-responsive (NR) sites in any state. Differentiating R from NR sites was improved when taking a 0-2' or 0-3' sample at the preplant or emergence stage and determining nitrate. Ammonium or potentially available organic N data did not improve soil test relationships but separation into parent material classes did. No testing method performed well when alfalfa was the previous crop.

MISSISSIPPI IMPROVE WATER QUALITY BY DEVELOPMENT OF MORE EFFICIENT METHODS OF APPLYING HERBICIDES. J. E. Hanks, C. G. McWhorter, and K. D. Howard, USDA-ARS, Stoneville, Mississippi. Report Period: 2/91 - 2/92.

Nozzles were identified for the air-assist system that provided uniform spray distribution when applying herbicides in paraffinic oil or water. Adjuvants to reduce the number of small droplets ($<100\ \mu$) were identified for both paraffinic oil and water. A device was invented to uniformly divide the liquid flow from a single pump to multiple spray nozzles. Clethodim herbicide applied at ultra-low-volume (ULV) in paraffinic oil decreased foliar wash off with rainfall as compared to conventional spray volumes in water. Evaluation of air-assist, ULV spray technology was initiated on a national basis by application of standardized field experiments in six other states. Research was initiated with sensor controlled intermittent sprayers that detect the presence of weeds and turn individual nozzles on/off as needed.

MISSISSIPPI, IOWA & TENNESSEE COTTON IRRIGATION AND THE EFFECTS ON HERBICIDE MOVEMENT, PERSISTENCE, AND CARRYOVER. C. E. Snipes, H. C. Pringle III, Mississippi State University, T. B. Moorman, Ames, IA, M. A. Locke, Stoneville, MS, USDA-ARS, and T. C. Mueller, University of Tennessee. Report Period: 4/90 - 2/92.

Adsorption and degradation of fluometuron were determined in soil from different depths of a Beulah silt loam profile. After the addition of 1450 ng fluometuron/g soil, degradation was adequately described by pseudo-first-order kinetics. However, these kinetics did not describe degradation after addition of 85 ng/g of [¹⁴C] fluometuron. At this lower concentration, degradation rates decreased as soil depth increased, but rates were not strongly correlated with either soil adsorption coefficients (K_d) or biomass. Approximately 56% of adsorbed fluometuron was desorbed in a single equilibration step, suggesting that a large fraction of adsorbed fluometuron is available for degradation. Decreased adsorption and degradation rates in lower soil depths increase potential leaching.

MISSOURI ALTERNATIVE MANAGEMENT SYSTEMS FOR ENHANCING WATER QUALITY IN AN AQUIFER UNDERLYING CLAYPAN SOILS. E. Alberts, USDA-ARS, Columbia, MO, and A. Prato, N. Kitchen, University of Missouri, **MSEA Project**. Report Period: 3/90 - 2/92.

Recharge of the aquifer underlying claypan soils varies from very slow to rapid, indicating zones of focused recharge. Influences of soil cracks, claypan discontinuities, biopores, and other preferential flow paths are being studied. Concentrations of triazines and alachlor were generally below the detection limit (0.2 ppb) from baseline sampling of 100 ground water wells distributed over the 28 square mile Goodwater Creek watershed. Ground water NO₃-N concentrations varied considerably among fields within the watershed. Wells that contain NO₃-N concentrations $> 10\ \mu\text{g/l}$ are usually associated with pastured areas or cropped areas that received animal manures prior to 1980. Atrazine concentrations in streamflow, particularly during surface runoff

periods, are always above the minimum detection limit. Lateral flow, which results from rainfall infiltrating the soil and moving laterally over the claypan surface, had the highest NO₃-N concentrations of any water sampled in this hydrogeologic system.

MISSOURI *TRIPSACUM* AND OTHER CORN RELATIVES AS RESOURCES FOR OPTIMIZING PRODUCTION PRACTICES THAT AFFECT GROUND WATER QUALITY. E. H. Coe, Jr., B. D. Barry, L. L. Darrah, USDA-ARS, Columbia, MO; and C. A. Blakey, Univ of Missouri. Rpt Period: 2/91 - 2/92. Information has been accumulated via reprints, phone conversations, visiting scientists, and visits to key laboratories. Corn materials with potential resistance to rootworm, *Tripsacum*, and teosinte and products of crosses between corn and *Tripsacum* have been identified or obtained. Field equipment for rootworm infestation has been constructed. Protocols and techniques for screening under controlled seedling growth conditions are being tested or are under development. Greenhouse work included observations on corn, *Tripsacum*, and teosinte. Corn seedlings (European corn borer resistant) and one commercial *Tripsacum dactyloides* were readily killed by first instar larvae of the western corn rootworm. Other species of *Tripsacum* and other varieties of *T. dactyloides* from CIMMYT and ORTSOM (France) scientists are under observation in the greenhouse. Data have been obtained for mapping restriction fragment length polymorphisms in an F₂ population between two parents of *T. dactyloides*, showing 19 linkage groups at this early stage from approximately 73 probed loci.

MISSOURI ROLE OF PLANT RHIZOSPHERE AND ASSOCIATED MICROFLORA IN PESTICIDES DEGRADATION. G. A. Buyanovsky, G. H. Wagner, University of Missouri, and R. J. Kremer, USDA-ARS. Report Period: 6/90 - 2/92.

In greenhouse experiments designed to assess the effect of plant systems on pesticide dissipation, new evidence of a complex interaction between roots, microorganisms, and xenobiotics has been discovered: 1) There were certain differences in carbofuran degradation subject to the closeness to corn roots. During the initial period of active plant growth (the first 30 days), the rate of degradation in close proximity to the roots was 1.5-2 times higher than in soil without roots. Later, no significant difference was found between the rhizosphere and the soil without roots. 2) A significant uptake and translocation of radioactive compounds (presumably carbofuran and degradation products) through the root system was detected. The highest concentration of absorbed xenobiotics was found in the corn leaves (14-32% of the total radioactivity applied to the soil), and the lowest was in the reproductive organs (0.12-0.16%).

MISSOURI MOVEMENT AND PERSISTENCE OF PESTICIDES IN HIGHLY AGGREGATED SOILS. C. J. Gantzer, G. A. Buyanosky, S. H. Anderson, S. Kapila, Univ of MO. Report Period: 7/89 - 2/92.

Transport of surface applied chemicals by percolating water was studied on a Menfro silt loam. Aldicarb and carbofuran were applied at 3 kg a.i./ha to 16 plots, 8 of which were near field capacity (wet) and the other 8 were near permanent wilting point (dry). Half of the dry and wet plots received irrigation immediately after chemical application and the other half received irrigation after 24 hrs. The transport and degradation parameters were estimated using CXTFIT. Estimated values of the dispersion coefficient, D, were higher for initially dry soil compared to initially wet. Estimated values for the retardation factor, R, for aldicarb were about 30% more than values whereas for carbofuran they were about 60% lower. To assess persistence of pesticides at depth in a soil, a laboratory incubation was done using ¹⁴C-labeled carbofuran and aldicarb. The top soil (0-30 cm) showed greater degradation rates than subsoil. The total amount of insecticides mineralized in the soil from the topsoil was 3-5 times greater than in the subsoil. The microbial community of the top of the soil has a much shorter adjustment time for added chemicals.

MISSOURI CT-MEASURED FRACTAL DIMENSION, LACUNARITY AND CRACK POROSITY RELATED TO TRANSPORT. R. L. Peyton, S. H. Anderson, C. J. Gantzer, J. U. Baer. University of Missouri-Columbia. Report Period: 9/91 - 2/92.

Materials of constant density containing simulated cracks of known width were fabricated and then were scanned by X-ray computed tomography (CT). This data will form the basis of the algorithm to quantify crack widths in soil cores from CT scans. A preliminary algorithm has been written to

take a digitized image of crack patterns and estimate the fractal dimension and lacunarity. Trial photographs of soil surface cracking have been taken under natural and controlled field conditions. Protocol for digitizing these photographs have been developed. Field studies have begun to study crack porosity. Fifty earth anchors have been installed in two claypan plots associated with the Missouri Management Systems Evaluation Area. Beginning this spring, weekly measurements will be made of vertical soil movement which will be converted into soil volume change and crack volume. Preliminary soil core breakthrough experiments have begun using Ct to relate small-scale dispersivity to fractal dimension and lacunarity.

MONTANA VALIDATION OF TRANSPORT MODELS FOR PREDICTING MOVEMENT OF AGRICHEMICALS THROUGH SOILS. W. P. Inskeep, A. H. Ferguson, R. H. Lockerman, J. W. Bauder, J. S. Jacobsen, Montana State University. Report Period: 9/89 - 8/91.

Field and laboratory experiments have been completed to determine the transport of herbicides and nitrogen under different moisture regimes. The solute transport model, LEACHM adequately predicted the breakthrough of solutes at different soil depths. Results using dicamba indicate the importance of water management and timing for preventing unnecessary movement of dicamba into groundwaters. Results for NO₃-N indicate that adequate fertilization for expected yield goals and prudent water management will not result in excessive NO₃- movement into groundwaters. Fertilization under dryland conditions may result in NO₃- accumulation and transport out of the root zone. These results are currently being used to formulate recommendations concerning best management practices for agrichemical use in Montana.

MONTANA VALIDATION OF SOLUTE TRANSPORT MODELS UNDER VARYING MOISTURE REGIMES. W. P. Inskeep, S. D. Comfort, R. H. Lockerman, and J. S. Jacobsen, Montana State University. Report Period: 9/91 - 2/92.

Current efforts to validate the solute transport model, LEACHM, for predicting chemical movement under cropped and fallow conditions show good agreement between observed and predicted results. LEACHM adequately predicted Br and PFBA transport under three different water regimes at 36, 66 and 96 cm soil depths. Accurately measured hydraulic conductivity parameters (e. g. variables in the Campbell's equation) are critical to model success. Experiments will continue for two field seasons to evaluate the transport and fate of herbicides under field conditions with varying water regimes. Future work will compare additional solute transport models including CMLS and PRZM. We have several experiments in progress to study herbicide transport in soil columns under laboratory conditions, with emphasis on investigating factors contributing to nonequilibrium transport such as preferential flow and herbicide reaction kinetics. An understanding of these processes will aid in the interpretation of results obtained under field conditions.

MONTANA, MINNESOTA & MAINE A LAND AND MICROCLIMATE ON-FARM INFORMATION SYSTEM FOR GROUNDWATER PROTECTION. J. S. Jacobsen, G. A. Nielsen, J. P. Wilson, Montana State University, P. C. Robert, University of Minnesota, and D. A. Tyler, University of Maine. Report Period: 6/91 - 2/92.

A field site has been identified in cooperation with the Gallatin County Conservation District, Soil Conservation Service, Extension Service and local farmer input. Detailed elevation data with Global Positioning Satellites (GPS), multispectral digital imagery and preliminary soil analysis have been completed. Soil, terrain, microclimate, and imagery GIS maps that depict nutrient leaching will be tested and the capabilities of an on-farm GIS for managing contrasting environments within fields will be improved. Soil specific fertilization practices have increased small grain farmers set returns an average of \$2-4/ha. Intuitively, by matching fertilization practices with soil and climatic variability, plant utilization will be maximized and water quality will be minimized. The application of new technologies will integrate soil specific fertilization practices.

MONTANA CROPPING SYSTEMS AND NON-POINT SOURCE GROUNDWATER POLLUTION. J. Johnson, D. Griffith, J. Bauder, J. Jacobsen, J. Wilson, J. Antle, Mont State Univ. Rpt Per: 9/91 - 2/92. Summarization of the 3400 well water samples from the Montana well water data base was completed. This data base was combined with the existing Geographical Information database for

Montana to allow statistical modeling of spatial geographical information and well water survey results. The combination of the well water survey data and the Montana Agricultural Potential Systems (MAPS) was the first step towards tying water quality test results to a geographical database and allowing "predictions" of water quality problems using a GIS system. Preliminary site selection for field work was completed.

NEBRASKA MOVEMENT OF AGRICULTURAL CHEMICALS BENEATH CONSERVATION TILLED-FURROW IRRIGATED LAND. D. E. Eisenhauer, R. B. Ferguson, F. W. Roeth, R. S. Spalding, University of Nebraska. Report Period: 7/91 - 2/92.

Advance time in furrow irrigation for four tillage and two cropping systems was measured. In a silt loam soil, there was an interaction between tillage and crop rotation. Conservation tillage slowed water advance in a continuous corn system but had no effect on advance in the corn/soybean rotation system. Core sampling was completed to 18 m in three tillage systems. Following collection, the 0.76 m plastic lined cores were frozen and stored. Indications from samples that have been analyzed are that nitrate-nitrogen accumulation in the vadose zone was significantly higher for the disk and surface plant system than for the ridge till and slot plant systems.

NEBRASKA QUANTIFYING NITRATE LEACHING UNDER CONTINUOUS CORN VERSUS A CORN-SOYBEAN ROTATION. G. W. Hergert, N. L. Klocke, D. G. Watts, J. P. Schneklath, University of Nebraska, and J. S. Schepers, USDA-ARS, Lincoln, NE. Report Period: 9/91 - 2/92.

Because this project was just initiated, there are no results available at this time. The objective of this research is to quantify and compare nitrate-nitrogen leaching losses from a corn-soybean rotation versus continuous corn. Fourteen state-of-the-art 90 cm by 240 cm monolithic percolation lysimeters are in place. The cropping systems have been in place for 7 years with each phase of the rotation present each year. There are four replications of each treatment. Plots are 24 m x 24 m. The lysimeter installation has been fully tested and equilibrated in the field during the past year. Leaching did occur during 1991 and samples were analyzed for NO₃-N and total leachate volume. Data will be available after the first full year of the project in 9/92.

NEBRASKA MANAGEMENT OF SOIL, WATER, AND NITROGEN RESOURCES TO PROTECT GROUNDWATER QUALITY. J. S. Schepers, D. D. Francis, W. W. Wilhelm, and J. F. Power, USDA-ARS, University of Nebraska, Lincoln, NE. Report Period: 5/90 - 3/92.

A rapid and reliable method was developed to measure the nitrogen (N) status of corn plants during the growing season. The goal was to develop a procedure that would allow producers to monitor the crop and thereby evaluate the need for supplemental N fertilizer that could be applied with irrigation water or by other means. Initially, leaf disks (1-cm diameter) were used to determine N concentrations and compared with portable chlorophyll meter readings. Correlations between leaf disk N concentrations and chlorophyll meter readings were not universally acceptable because of problems related to different corn hybrids, stages or growth, and methods of fertilizer N applications. Agreement between the two methods was good for individual fields. Comparing leaf N status from an adequately fertilized part of the field with that from the rest of the field proved to be an excellent way to internally calibrate chlorophyll meters. In practice, this approach was able to detect crop N stresses and permit fertilizer application without reduction in yield.

NEBRASKA REAL-TIME MEASUREMENTS OF HERBICIDE PERSISTENCE IN GROUND WATER. Roy F. Spalding and Vitaly Zlotnik, University of Nebraska; Douglas M. Mackay, William W-G Yeh, and James F. Barker, University of Waterloo, Canada. Report Period: 4/91 - 2/92.

Data collection for the natural gradient herbicide injection test at Fremont, Nebraska is complete. A solution containing bromide, atrazine, metolachlor, alachlor, and cyanazine was injected on September 18 and monitored in 7 fences of multilevels over the next 2 months. This allowed for completion of the field work by one mixed injection. An agronomy Ph.D. graduate student is involved with this study. The 1343 pesticide and bromide analyses are presently being interpreted. Data collection for the induced gradient test at the Borden aquifer has also been completed. Six herbicides and chloride were injected. The preliminary interpretation of the data was included in an abstract of the 1991 fall meeting of the American Geophysical Union. Data from both studies suggests that atrazine is quite recalcitrant to degradation at normal ground water pHs.

NEBRASKA MANAGEMENT OF IRRIGATED CORN AND SOYBEANS TO MINIMIZE GROUNDWATER QUALITY. D. G. Watts, R. F. Spalding, and J. S. Schepers. University of Nebraska and USDA-ARS, Lincoln. MSEA Project. Report Period: 5/90 - 3/92.

Research was begun to evaluate the impact of management systems for monoculture irrigated corn, on groundwater quality in Nebraska's Central Platte Valley. These systems include conventional furrow irrigation and N management practices, surge flow irrigation and BMP N practice, and center pivot irrigation with fertigation timed through use of a chlorophyll meter. The surge and pivot systems reduced water application by 44% and 64%, while N amounts were cut by 39% and 83% with no yield loss. Twenty-five research projects were initiated under the MSEA project umbrella to develop new or improved BMP's for management of irrigation water and agrichemicals. Chlorophyll meter use and surge irrigation technology are being transferred to farmers.

NEW MEXICO CHEMICAL TRANSPORT AND PERSISTENCE IN A FURROW IRRIGATED NO-TILL MANAGEMENT SYSTEM. N. B. Christensen, J. Schroeder, T. L. Jones, New Mexico State University, J. M. H. Hendrickx, New Mexico Tech. Report Period: 5/91 - 2/92.

The project to study the transport and persistence of metolachlor under no-till and conventional till conditions was initiated in 1989. Characterizing the hydrological properties of the soil under the two tillage systems is currently under way. Metolachlor and organic tracers have been applied preemergence each year and soil samples collected throughout the season. Metolachlor dissipation from the conventional till and no-till areas have varied considerably. One dimensional transport simulations of bromide and metolachlor are currently being done using LEACHM, however no conclusive results are available at this time.

NEW YORK ELECTROCHEMICAL TREATMENT OF PESTICIDE WASTEWATER. A. T. Lemley, K. Pratap, Cornell University. Report Period: 6/90 - 3/92.

Electrochemical treatment of aqueous solutions of atrazine, metolachlor, alachlor, and picloram in laboratory experiments shows good promise for degradation of these wastes. An electrochemical Fenton's system that allows precipitation of ferrous iron in the presence of hydrogen peroxide at neutral pH values results in greater than 90% removal of the parent compound. Significant amounts of removal are due to degradation of the parent. The degradation follows first order kinetics in the pesticide, and products are observed as HPLC chromatographic peaks. Continued studies on formulated products and field samples containing the above herbicides (and cyanazine) and studies on degradation schemes will confirm the usefulness of this methodology in treatment of pesticide rinsates.

NEW YORK & MASSACHUSETTS REDUCING GROUNDWATER POLLUTION: A SYSTEMS ANALYSIS. C. A. Shoemaker and G. White, Cornell University and D. N. Ferro, University of Massachusetts. Report Period: 9/90 - 2/92.

The project objective is a holistic analysis of source control of pesticide pollution by evaluating the simultaneous effect of a given pesticide program on groundwater pollution, yields and economic return. The analysis will integrate three models describing the movement of pesticide into groundwater, the dynamics of an insect pest, Colorado potato beetle, the growth (given insect defoliation) of the potato crop. An insect model has been developed and is being modified to consider the effects of residual level of pesticide on pest survival rates. In summer 1991 field experiments were conducted to obtain these new rates. Residual activity (under field conditions) was determined by bioassay for M-One, M-One Plus, Asana, Vydate, Thiodan and Kryocide. In addition an improved weather generator has been developed and fit to study sites in the project. The insect model has been linked to a model of plant growth and to PRZM, a simulation model of pesticide movement. Preliminary results indicate that pesticide applications that are adjusted to the densities of pests in the field can provide more economic control with less groundwater pollution than pesticide applications that are applied on a fixed schedule.

NEW YORK INTERACTION OF PREFERENTIAL FLOW AND BIODEGRADATION IN HETEROGENEOUS SOILS. T. S. Steenhuis, M. Alexander, B. Pivetz, J. W. Kelsey, Cornell University. Report Period: 7/90 - 2/92.

The experiments involving biodegradation of organic substances in soils with preferential flow paths in small and large undisturbed columns are near completion. In these columns, macropore and matrix flows were sampled separately. Paranitrophenol (PNP) was used as the organic substance, as its concentration could be easily measured. The results show that, despite the fast flow through the macropores, the applied organic substances were always degraded after an initial adjustment period at which time the bacterial population increased. Finally, these experiments begin to explain why the aquifer is seldom contaminated in structured clay soils where preferential flow is prevalent and pesticides are transported downward to the groundwater.

NEW YORK & NEW MEXICO LOCATING SOIL LAYERS IN THE VADOSE ZONE WITH NONDESTRUCTIVE METHODS: ASSESSING VULNERABILITY TO CONTAMINATION OF AQUIFERS. T. S. Steenhuis, J.-Y. Parlange, L. M. Cathles, Cornell University; J. M. H. Hendrickx, J. Schlue, New Mexico Institute of Mining and Technology. Report Period: 8/91 - 2/92.

Knowledge of the location of the subsurface textural layers is important for assessing the potential of groundwater contamination and for locating solute samplers in the vadose zone. The hypothesis of this research is that ground penetrating radar, in combination with the electromagnetic induction method, provides a fast and nondestructive method for finding these layers, as proven in initial experiments in New Mexico and Delaware in light-textured soils. Research in the next two and a half years will further determine the limits of the proposed methods.

NEW YORK & MARYLAND PARAMETERIZATION OF TILLAGE EFFECTS ON SOIL HYDRAULIC PROPERTIES AND AGRICHEMICAL LOSSES. H. M. vanEs, J. L. Hutson, Cornell University, and R. L. Hill, University of Maryland. Report Period: 10/91 - 2/92.

Four experimental sites have been selected. The New York sites are located on Honeoye-Lima silt loam soil (Glossoboric Hapludalfs), which is representative of Western New York corn growing region and Rhinebeck clay loam soil (Aeric Ochraqualf) which represents the fine-textured soils in Northern New York. Both sites were used for alfalfa-grass production. Undisturbed soil cores were obtained and are being analyzed for soil water characteristic curves and saturated hydraulic conductivity. In Maryland, two sites were chosen on Bertie-Mattapex silt loam soils (Aquic Hapludults) in Wye Mills, MD which are representative of Maryland's Eastern Shore. One site has been in continuous corn under conventional and no-till management since 1988. The second site has been cropped to soybeans and will be established in spring 1992 and is located under an overhead tract irrigation system to allow for controlled rainfall application. Soil infiltrometers and portable rainfall simulators are being constructed. The LEACHM model has been adapted to include preferential water and solute flow using a scaling approach.

NEW YORK MAPPING GROUNDWATER CONTAMINATION POTENTIAL USING INTEGRATED SIMULATION MODELING AND GIS. R. J. Wagenet, R. B. Bryant, S. D. DeGloria, Cornell University, Ithaca, NY, and R. G. Perritt, USDA-SCS, Syracuse, NY. Report Period: 9/89-2/92.

Soil, climate, land-use and terrain data in a GIS were used to identify areas which may be a source of pesticide leaching. A computer model (LEACHM), using soil survey data, was used to evaluate leaching potential. Representative rainfall distributions were selected for each climate region using leaching indices for twenty years of data. Evaluations of the leaching hazards of atrazine, cyanazine and pendimethalin on corn in Connecticut, Rhode Island and New York are complete. The study has shown the relative importance of soil data, climatic data and assumptions regarding lower boundary conditions and organic matter distribution in the soil profile.

NEW YORK & CONNECTICUT PROTECTING GROUNDWATER FROM NITRATE ON DAIRY FARMS IN THE NORTHEAST. R. J. Wagenet, S. D. Klausner, and R. A. Milligan, Cornell University, S. R. Kaffka and V. R. Kanneganti, Sunny Valley Foundation, New Milford, CT. Rpt Period: 5/90 - 2/92. This study was initiated to investigate the benefits of incorporating orchardgrass into corn-alfalfa rotations for reducing manure-N loss to groundwater. Slurry and bedded manure at 150, 300 and 450 kg N ha⁻¹ yr⁻¹ were split applied one, two or four times for 2 years. Data were collected for

crop yield, N uptake, and soil and groundwater nitrate-N. It appears that orchardgrass may be used as an effective 'nitrogen sink crop' to absorb excess manure-N on dairy farms. The crop removed 423 kg N ha⁻¹ y⁻¹ in 11,400 kg of forage dry matter. No significant N losses were detected in deeper soil horizons or in the groundwater, even at 80 MT ha⁻¹ y⁻¹ of manure application (450 kg N).

NORTH CAROLINA PREFERENTIAL MOVEMENT OF WATER AND SOLUTES THROUGH SOIL/SAPROLITE SEQUENCES. A. Amoozegar, S. W. Buol, W. P. Robarge, M. J. Vepraskas, and R. M. Kretschmar, North Carolina State University. Report Period: 7/91 - 2/92.

Two sites in the Piedmont region of North Carolina were evaluated for field and laboratory studies of solute and colloidal clay transport through macropores. Intact core samples, 6.6 cm diameter and 10 to 20 cm long, were collected from the Bt horizons and their underlying saprolite at each site. A large pit was constructed at one of the sites for profile description, excavation of large soil blocks, and collection of samples for chemical, physical, and mineralogical characterization of the soil/saprolite continuum. For studying movement of soil particles through soil and saprolite, clay colloids were separated from the Ap horizons of three different Ultisols and tested for their ability to coagulate in suspensions having different chemical compositions. The results indicated that humic substances may retard coagulation of clay colloids in a suspension.

NORTH CAROLINA & VIRGINIA REMOVAL OF NONPOINT SOURCE POLLUTION BY VEGETATED AND RIPARIAN BUFFERS. J. W. Gilliam, J. E. Parsons, R. B. Daniels, North Carolina State University, and T. A. Dillaha, Virginia Polytechnic and State Univ. Report Period: 7/91 - 2/92.

Three field experiments designed to evaluate sediment and pollutant movement from agricultural landscapes through both grass buffers and riparian areas are being monitored in North Carolina and Virginia. The two field sites in North Carolina, one in the Piedmont Region (near Raleigh, NC) and the other in the Coastal Plain region (near Kinston, NC) are instrumented. The third site is currently being installed in Ridge and Valley Region of Virginia. Each site enables comparisons of surface runoff from agricultural source areas filtered through 2 lengths of grass buffers (4.3 m and 8.5 m lengths) and riparian buffers (4.3 and 8.5 m lengths). Detailed storm hydrographs and surface water quality during each rainfall event are measured. Our initial storm data indicates that grass buffers can reduce sediment loading by more than 75% while reducing surface chemical loading by as much as 50%. Development has begun on a storm by storm model to study water-sediment-chemical flow through these buffers. Additional modeling work is also starting to evaluate the application of existing hydrologic/water quality models such as CREAMS to this problem.

NORTH CAROLINA GROUND WATER CONTAMINATION POTENTIAL USING MODELS, GIS, AND REMOTE SENSING. S. Khorram, R. L. Huffman, North Carolina State Univ. Rpt Per: 6/90 - 2/92.

The major goals of this project are to integrate satellite imagery; digital maps of soils, topography, field boundaries, weather stations, and watersheds; and related multi-temporal tabular databases into a GIS that can be used with GLEAMS to predict pesticide leaching for individual agricultural fields and larger regions. To date the software, satellite imagery, base maps, coverages, and tabular databases required have been obtained. Digitizing and integration of the databases in Arc/Info are essentially complete. The building of a GIS to GLEAMS interface is well underway with several essential components completed. The results will (1) show how widely varying data types can be integrated into a vector based GIS, and (2) demonstrate how GLEAMS and other complex water-quality models can be used efficiently within a GIS framework for repetitive or large area analysis.

NORTH CAROLINA EFFECTS OF WATER TABLE MANAGEMENT ON GROUNDWATER QUALITY. R. W. Skaggs, J. W. Gilliam, T. J. Sheets, R. O. Evans, J. E. Parsons, C. L. Munster, North Carolina State University. Report Period: 6/90 - 2/92.

A 34 acre research site with subsurface drains was instrumented to measure surface and subsurface drainage and ground water quality. Field studies to document nutrient and pesticide fate were conducted under free drainage, controlled drainage and subirrigation conditions. The two-dimensional ground water flow and chemical transport model, VS2DT, was modified to include

subsurface drains and the transport of more than one chemical. The data from the field studies were used to test the simulations. Subsurface aldicarb losses were less from subirrigation and controlled drainage than from free drainage, but all losses were less than 0.02% of the amount applied.

OHIO SURFACE-SUBSURFACE WATER AND CHEMICAL MOVEMENT AND INTERACTIONS ON AGRICULTURAL WATERSHEDS. J. V. Bonta, W. M. Edwards, L. B. Owens, USDA-ARS, Coshocton, OH. Report Period: 1/90 - 2/92.

Urban's Knob (UK), located at the ARS Coshocton location, is an isolated 12-ac hilltop in which an impervious underclay outcrops along its periphery. Instrumentation efforts are continuing on UK to achieve the project objectives and to understand the subsurface flow system on the area. Twenty-five wells and 20 rain gages have been installed. Samples from wells, rainfall and runoff measurements, and field observations of water-level recovery in wells show the importance of quantifying spatial variability of natural characteristics. Knowledge of spatial variability is important for representative sampling of study areas, and for successful modeling and extrapolation of results. The very low baseline concentrations of simazine, cyanazine, alachlor, and atrazine found in UK ground water suggest that effects of the superimposed agricultural management practice in ground water will be directly attributed to the practice. Future investigations on UK will include studies of surface/ground-water interactions (quantity and quality), rainfall characterization, runoff generation, ground-water quality and hydraulic variability, and ground-water modeling in the fissured hilltop.

OHIO & INDIANA ROLE OF WATER TABLE POSITION AND HISTORY ON THE FATE OF SUBSURFACE CONTAMINANTS. L. C. Brown, S. J. Traina, The Ohio State University, R. F. Turco, Purdue University, and W. A. Dick, The Ohio State University. Report Period: 7/91 - 2/92.

Two laboratory components are soil column solute transport and chemical/microbiological characterization of soil profile. Third component is modification/evaluation of ADAPT/GLEAMS computer models to predict nutrient and pesticide transport. Nitrate, bromide, alachlor, atrazine, metribuzin will be studied on 4 soils (3 hydric) being sampled for columns (30x100cm) and profile characterization. Initial site/soils investigations are underway. Two column sets from associated NCRPIAP work will be used with two additional column sets, which will be collected with a new device for large-diameter, undisturbed cores. Solute transport work planned for later in 1992. Other work has focused on methods development, and soil sample preparation from 3 of 4 soils. Analytic protocol for measurement of dissolved pesticides by HPLC has been developed for batch adsorption experiments. Recently constructed and calibrated HPLC with prep-scale columns will be used to obtain breakthrough curves for pesticides. Preliminary microbiological work indicates that both atrazine sorption and total microbial biomass in surface soils (0-30 cm) is much greater than at any other depth to 100 cm.

OHIO WEED MANAGEMENT SYSTEMS TO REDUCE GROUNDWATER CONTAMINATION IN NO-TILL CORN. J. Cardina, W. A. Dick, and S. Kent Harrison, Ohio State University - Ohio Agricultural Research and Development Center. Report Period: 7/91 - 2/92.

Field studies were initiated to 1. measure herbicides in runoff and leachate water in no-till corn with three weed management systems and 2. measure weed control and crop productivity responses to alternative weed management systems. In the initial few months of this project field lysimeters were set up and calibrated and varying weed populations and cover crops were established. Data on herbicide movement, associated hydrology, and weed management will be collected beginning in 1992.

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OHIO WATER TABLE MANAGEMENT FOR CROP PRODUCTION AND GROUND WATER QUALITY PROTECTION. N. R. Fausey and R. L. Cooper, USDA-ARS; A. D. Ward, T. J. Logan and J. G. Streeter, Ohio State University. Report Period: 1/90 - 2/92.

As planned, the Wooster site was managed as a corn/soybean rotation in 1990 and 1991. Soybean yields averaged 67 bu/ac and corn 196 bu/ac over the 2 years. The water table was maintained at approximately 12 inches below the soil surface from June 15 to September 15 each year and the high yield management system was used. Yields with drainage alone were 42 bu/ac for soybeans

A27

CG

67
607
42

196
123
607

and 123 bu/ac for corn using the high yield management system. Perched ground water and subsurface drainflow samples were obtained biweekly from May through September and once each month during the remainder of the year. The samples were analyzed for atrazine, alachlor, metolachlor, and nitrate. High levels of nitrate are observed in the shallow ground water beneath the subirrigated plots. Pesticides were seen at the top of the shallow ground water briefly after surface application. The construction of 12 new water table management plots at Hoytville was completed in late summer of 1991. Hydrologic tests of lateral and deep seepage were carried out in the Fall. Data collection will begin in these plots in 1992.

OHIO & MICHIGAN EFFECT OF SORPTION ON FATE OF PESTICIDES IN SUBSURFACE ENVIRONMENTS. S. J. Traina, G. K. Sims, T. J. Logan, Ohio State University and S. A. Boyd, Michigan State University. Report Period: 6/89 - 2/92.

We have studied the effects of sorption on the degradation of pyridine, by *Micrococcus luteus*, 2-methyl pyridine, by *Arthrobacter* and naphthalene by *Pseudomonas putida*, in suspensions of specimen clay minerals, and specimen clays coated with humic acid and alkylammonium surfactants. Additionally we have examined the affects of dissolved humic acid on pyridine degradation by *Micrococcus luteus*. In general, sorption to mineral and/or organo-mineral surfaces, and complexation by dissolved humic acid increased the time required for complete degradation of the parent compounds. The degradation rates of sorbed pyridine and 2-methyl pyridine were less than in pure solutions, but sorption appeared to increase the half-life of naphthalene by increasing the lagtime prior to the onset of degradation. Pyridine degradation at pH 5 was enhanced by sorption to smectite and 2-methyl pyridine degradation was greater in the presence of kaolinite than in clay free solutions.

OHIO ASSESSING AND MODELING WATER QUALITY BENEFITS OF WATER TABLE MANAGEMENT SYSTEMS. Andy Ward, Terry Logan, Scott Bair, The Ohio State University, Norm Fausey, USDA-ARS, Columbus. Report Period: 7/90 - 2/92.

Soil characterization and macropore research has been conducted at Wooster. A Plaster of Paris technique has been used in conjunction with ring infiltrometer tests. Bulk density, particle size analysis, and permeability testing has been conducted on soil cores. Excellent progress has been made with the ADAPT model. The model is an extension of GLEAMS which includes drainage, subirrigation, improved snowmelt and runoff algorithms, deep seepage, and macropore flow due to cracking. Data from an experiment at Castalia were used to validate the hydrologic components of the model. The pesticide transport capabilities of the model have been completed and tested with data from Wooster and Hoytville. The model gave reasonable predictions which are in acceptable agreement with the observed values. A statistical analysis of 3 years of water quality data for Wooster showed that metolachlor movement into the ground water is primarily a function of the proximity of the water table to the surface, precipitation within the first few weeks after application, and preferential flow.

OHIO THE OHIO BURIED VALLEY AQUIFER MANAGEMENT SYSTEMS EVALUATION AREA. Andy Ward, Scott Bair, Terry Logan, Sue Nokes, The Ohio State University, Norm Fausey, Steve Workman, USDA-ARS, Steve Hindall, Martha Jagucki, USGS. **MSEA Project.** Report Period: 4/90 - 2/92. The Ohio MSEA is part of a regional study to develop improved farming systems which reduce adverse impacts on water resources while maintaining productivity and profitability. Progress has been excellent with the following activities completed on schedule: the installation of the monitoring systems; site characterization activities; and the initiation of data collection and farming activities. More than 6,000 water, soil, and plant samples were obtained during the 1991 growing season and 25 specific research projects are in progress. Extensive documentation includes: 5 volumes describing the Ohio Project (project description, administration, two protocol documents, and a QA/QC document); a regional project document; and several brochures, newsletters, and extension fact sheets. Extensive regional coordination has been undertaken and project personnel have participated in many regional meetings, workshops, and professional society meetings. An External Advisory Board was appointed and has met on two occasions.

OKLAHOMA & FLORIDA AGRICULTURAL CHEMICAL IMPACT EVALUATION AND MANAGEMENT SYSTEM. D. L. Nofziger, C. T. Haan, Oklahoma State University, and A. G. Hornsby, University of Florida. Report Period: 7/89 - 7/91.

The objective of this project was to develop a computer-based system to estimate the risk of ground water contamination by pesticides. The system was developed by interfacing a chemical transport model, CMLS, to a geographical information system, creating a weather interface for the model, and building the required databases. The system was demonstrated to federal, state, and local agencies, presented at numerous national meetings including the Water Technology Board of the National Academy of Science, and used in training courses. The Oklahoma Department of Agriculture is adopting it. The system is being used to make watershed assessment in the Lake Manatee Water Quality Demonstration Project and the Karst Cropland HUA project in Florida, and in Lake Creek watershed and Tipton Water Quality projects in Oklahoma. This system will facilitate informed decision-making wherever it is used.

OKLAHOMA, FLORIDA & NORTH CAROLINA ECONOMICS OF MANAGING PESTICIDES TO REDUCE WATER QUALITY DEGRADATION. D. L. Nofziger, Oklahoma State University, A. G. Hornsby, University of Florida, Dana Hoag, North Carolina State University. Report Period: 7/91 - 2/92.

The purpose of this research is to develop a scientifically sound decision-support system to aid peanut farmers in selecting pesticides and managing production systems to minimize risk of degrading groundwater quality. The system incorporates economic as well as environmental considerations. Work to date has focused on development of data bases and knowledge bases required in the system and upon implementation and evaluation of a prototype system. A simplified prototype is operational for herbicide selection. Methods of reducing the time required for Monte Carlo simulations of chemical transport are also being evaluated. The basis of the system has been reviewed and accepted for publication in the Journal of Environmental Quality.

OKLAHOMA ECONOMIC IMPACTS OF GROUND WATER QUALITY MANAGEMENT. P. E. Norris, H. P. Mapp, D. L. Nofziger, C. T. Haan, Oklahoma State University. Report Period: 7/91 - 2/92.

Enterprise budgets have been developed for a representative peanut farm in Caddo County, Oklahoma. Preliminary runs of the CMLS physical transport simulation model indicate the potential for movement of some agricultural chemicals to ground water in the study area. Irrigation management practices are particularly important as indicators of chemical movement. However, the quantity of chemical leached, the time required for chemical movement, as well the distance moved by the chemical all vary widely depending upon soil type and weather patterns. This information will be used to determine the probability of chemicals reaching ground water under alternative agricultural management scenarios.

OKLAHOMA PREVENTION OF GROUND AND SURFACE WATER CONTAMINATION BY NEW AGRICULTURAL MANAGEMENT SYSTEMS. S. J. Smith, A. N. Sharpley, and J. W. Naney, USDA-ARS, Durant, OK. Report Period: 2/91 - 2/92.

Field, laboratory, and model simulation studies were conducted to assess the impact of animal waste management, use of cover crops, and fixed soil N on the potential movement of agricultural chemicals to surface and ground water in the Great Plains. The long-term application of poultry litter increased the surface soil total N and P content a respective 10- and 22-fold compared to untreated soils. Model simulations show that litter applications have the potential to enrich the nutrient content of runoff, emphasizing the need to carefully manage repeated applications to minimize potential runoff losses. Cover crops reduced soil, N, and P loss (60-90%) in runoff from several Southern Plains watersheds, although the bioavailable portion in soluble and particulate forms, may increase (20-40%). Accurate predictions of N and P transport in runoff from watersheds, with and without cover crops, were obtained using kinetic and enrichment ratio approaches. Preliminary results indicate the ammonium-fixing properties of illitic soils may be an important management factor.

OKLAHOMA & TEXAS WATER QUALITY IMPLICATIONS OF PLAYA LAKE CONTAINMENT OF FEEDLOT WASTES. S. J. Smith, A. N. Sharpley, and J. W. Naney, Durant, OK, and B. A. Stewart, Bushland, TX, all USDA-ARS. Report Period: 2/91 - 2/92.

In 1991, a playa that had been used for more than 20 years to contain beef cattle feedlot runoff was sampled at four locations to a depth of 17 m. In addition, a runoff retention pond constructed in 1974 on the more permeable side slope of a playa was sampled at 18 locations to depths ranging from 3 to 10 m. Less than 3 mcg/g $\text{NO}_3\text{-N}$ were found below 1 m in the playa samples. Ammonium-N concentrations in the top 2 m of the playa bottom ranged from about 20 to 125 mcg/g, and values of 5 to 10 mcg/g were sometimes found at depths beyond 10 m. Therefore, some limited percolation is suggested. In contrast to the playa bottom, the samples from the more aerobic area around the retention pond contained higher concentrations of NO_3 but lower amounts of NH_4 . The highest $\text{NO}_3\text{-N}$ concentrations were about 250 mcg/g below 3 m. Additional studies are needed, but these results indicate little evidence that N movement through playa bottoms is degrading the quality of the underground aquifer.

OREGON NONPOINT SOURCE POLLUTION AND AGRICULTURAL PRACTICES: SOURCE TERM, MIXING ZONE, AND THE STEADY STATE CONDITION. L. Boersma, R. Mason, Oregon State University. Report Period: 9/89 - 2/92.

The hypothesis being tested is that for a given farm management system concentrations of chemicals applied at the soil surface can never rise above a certain value--"the steady state" concentrations--in the groundwater because of the dynamic interactions between rate of application, vadose zone transport, and groundwater flow. This concept is not recognized in development of policy. Validation of the hypothesis requires determination of application--the source term--and hydrodynamic behavior in groundwater--the sink term. Survey of use of fertilizers and weed and pest control chemicals was completed as planned: One hundred and fifty farmers in two different climate zones participated by completing a diary on which they made daily entries of each activity as it occurred on the field selected for the survey. Responses have been entered on a computer data base and analysis is in progress. Mathematical models were developed for determination of the "steady state" concentration. Simulations show how concentrations are determined by spatial variability of the hydraulic conductivity field. Results emphasize uncertainty associated with point sampling in large aquifers.

OREGON DYNAMIC MODELING OF ALTERNATING-FURROW IRRIGATION TO MINIMIZE NITRATE LEACHING TO GROUNDWATER. A. R. Mitchell, C. C. Shock, G. M. Perry, Oregon State University. Report Period: 4/91 - 2/92.

The soil hydraulic properties were obtained for use in the model. Both the Eastern and Central Oregon soils' conductivity values were determined by the instantaneous drainage profile method. The van Genuchten equations for the soil water retention isotherm have been determined. A model, SWMS_2D, has been selected for 2-D solution of the water and solute flow problem in furrow irrigation. In order to validate the water flow model for furrow irrigation, a grid of soil sensors was developed for collecting soil moisture at one-minute intervals that will detect the progress of the wetting front. Granular Matrix Sensors (Watermark) were connected to a multiplexor and datalogger in a field furrow. The sensor response time was determined to be less than one minute. In 1992, alternate-furrow irrigation experiments will be conducted on a wheat field following onions and on peppermint.

OREGON FATE AND CYCLING OF ^{15}N -LABELLED DAIRY MANURE. D. D. Myrold, J. A. Moore, M. Gamroth, and J. E. Thies, Oregon State University. Report Period: 6/90 - 2/92.

^{15}N -labelling of dairy manure was accomplished as planned. Time course manure samples were fractionated to determine atom percent ^{15}N and N content of the $\text{NH}_3\text{-N}$, amino sugar-N, amino acid-N, and acid insoluble-N fractions. Kinetics of label incorporation into the different fractions was described. A poster detailing these results was presented at the American Society of Agronomy Annual Meeting in Denver, CO, October 1991. Manure with the higher and more homogeneous ^{15}N label has been applied at three rates (200 kg N ha⁻¹ yr⁻¹, 400 kg N ha⁻¹ yr⁻¹, and unamended) to PVC mesocosms at three field locations in Oregon beginning in three different seasons: spring (May 1991); fall (Nov 1991); and winter (Feb 1992). Mesocosms have been sampled every

three months following application of ^{15}N -labelled manure to determine plant uptake, gaseous N losses (NH_3 volatilization and denitrification), leaching losses, and transformation of N into various organic and inorganic N pools.

OREGON & NEW YORK DEVELOPMENT AND TESTING OF WICK LYSIMETERS FOR OBSERVATION OF SOLUTE TRANSPORT. J. S. Selker, J. Moore at Oregon State University, and T. S. Steenhuis, J.-Y. Parlange at Cornell University. Report Period: 6/91 - 3/92.

The primary goal of this project is the development and testing of passive capillary samplers (PCAPS) for monitoring water quality in soils. A central problem faced in the design and construction of PCAPS is control over the physical properties of the capillary wicks. We have identified and obtained wick samples from 12 producers, with 32 wick varieties presently under testing. Of particular interest are samples obtained from a producer (Amatex Corp.) who can consistently control the density of weave of the wick fabric which enhances our ability to match the capillary properties of particular soils to samplers. Structural components of two PCAPS sampler designs are being assembled for spring 1992 installation. These samplers incorporate new one-piece cast aluminum hard-anodized frameworks and molded fiberglass sampler bodies. Ongoing tests of the capillary properties of wicks show significant differences between wicks of similar appearance. These results are expected to lead to improvements in PCAPS sampler performance.

PENNSYLVANIA SOIL MANAGEMENT OF RESIDUAL MANURE NITROGEN AFFECTING NITRATES IN GROUND WATER WITHIN LIMESTONE TERRAIN IN LANCASTER COUNTY, PA. D. E. Baker, A. T. Phillips, J. P. Senft, C. S. Baker, Penn State University. Report Period: 7/90 - 2/92.

Dairy management programs over the past 30 years increased crop yields 150%. In the mid 80's it was found that the existing systems were causing nitrate-N pollution of ground water. Water pollution is associated with liquid manure storage systems which allowed for increased number of cows and a decrease in straw bedding. For these well aerated soils, it was found in 1991 that additions of wastes with a high C:N ratio applied with and without additional manure-N increased the microbial immobilization of excess N and prevented the leaching of excess nitrate-N to ground water. The conclusion is that many farms do not have an excess of N, but rather a deficient quantity of manure carbon.

PENNSYLVANIA USE OF MICROORGANISMS OR ENZYMES FOR DECONTAMINATION OF PESTICIDE-POLLUTED SOIL AND WATER. J.-M. Bollag, S.-Y. Liu, Penn State Univ. Rpt Per: 10/89 - 9/91.

In an effort to develop methods to detoxify pesticides, we studied the biotransformation of metolachlor. Various enrichment techniques were used to isolate metolachlor-transforming microorganisms. The most common transformation reactions observed with various bacteria and fungi were dechlorination, demethylation and hydroxylation of the side chains. In contrast to the results obtained with pure cultures, we demonstrated mineralization of metolachlor with soil samples. Our results suggest that while a single organism may not be able to completely biodegrade metolachlor, a microbial population is able to mineralize the herbicide. These findings may prove useful to an understanding of the mechanisms involved in the microbial degradation of pesticides and for developing methods of removing xenobiotics from contaminated soils and waters.

PENNSYLVANIA ESTIMATION OF ANION TRANSPORT IN SOILS USING ZERO-TENSION LYSIMETERS. R. H. Fox and D. D. Fritton. Pennsylvania State Univ. Report Period: 9/89 - 8/91.

The 3-yr average nitrate-N concentrations in leachate collected in zero-tension pan lysimeters at the economic optimum N fertilizer rate were 18.8 and 19.3 mg/L for non-manured and manured corn, respectively. The collection efficiency of the 18 lysimeters as estimated by Br^- recovery and water budget analyses ranged from 13 to 92% with an average of 54%. Using efficiency-corrected values, the amount of nitrate-N leached at the economic optimum N rate in the non-manured corn ranged from 80 to 133 kg/ha with an average of 107 kg/ha or 36% of the N applied. The leaching model LEACHM adequately predicted water flow, but was only moderately successful in predicting Br^- or nitrate leaching due to the model's inability to model solute movement in well-structured soils where macro-pore flow predominates.

PENNSYLVANIA NITRATE LEACHING IN CONTINUOUS CORN AND MANURED CORN-ALFALFA ROTATIONS. R. H. Fox, D. D. Fritton, W. P. Piekielek, J. D. Toth, Pennsylvania State University. Report Period: 10/91 - 2/92.

Nitrate leaching losses from N fertilized corn and from alfalfa are being measured with zero-tension lysimeters at a depth of 1.2 m beneath a field in a corn-alfalfa rotation. The 1991 growing season was very dry, with a growing season rainfall deficit 188 mm below the 30-year average. Eighty mm of irrigation water from a drip emitter system was applied to both crops. Despite irrigation, the drought apparently caused some yield loss in the alfalfa, with estimated total production 5.84 Mg ha⁻¹. The irrigation allowed maximum corn grain yields of 9.25 Mg ha⁻¹, which are similar to those normally observed at this site. The economic optimum N rate was 185 kg ha⁻¹. There was very little leachate collected, and most (84%) was collected below the corn. The flow-weighted mean NO₃-N concentrations in the corn leachate ranged from 2.11 mg L⁻¹ in the 0 kg ha⁻¹ fertilizer plots to 12.06 mg L⁻¹ in the 200 kg ha⁻¹ plots. Alfalfa leachate concentration averaged 3.70 mg L⁻¹.

PENNSYLVANIA MICROENCAPSULATION AND ADJUVANT EFFECTS ON HERBICIDE LEACHING AND PERSISTENCE. J. K. Hall, R. O. Mumma, N. L. Hartwig, L. D. Hoffman, Penn State University. Report Period: 5/90 - 2/92.

Greenhouse bioassays were completed on soil collected in late fall of 1990 and 1991 from the surface 5 and 15 cm of a rotation study involving two adjuvants applied with atrazine and metolachlor. Growth suppression of the test crop (oats) was evident for both adjuvant-amended herbicide treatments. Atrazine-induced tissue damage was most evident and oat yields were consistently lower at the recommended 1.7 kg/ha rate. In 1991, yields were lower on NT than CT-sampled soil (5 cm). Adjuvant-induced effects were not as defined for metolachlor as with atrazine. Chemical analyses of these soils is in progress; general analysis of bioassay results indicates that adjuvant-herbicide spray combinations have the potential of reducing herbicide losses by leaching in the field. In another bioassay, comparing microencapsulated and standard formulations of these herbicides, oat yield reductions were greatest on atrazine-treated soil sampled from the surface 5 cm, and, in general, yields were comparable between formulations.

PENNSYLVANIA KARST AQUIFER POLLUTION ASSAY BY VULNERABILITY INDEX DETERMINATIONS. D. A. Kurtz, R. R. Parizek, Pennsylvania State Univ. Rpt Per: 5/91 - 2/92.

Assessment of the groundwater vulnerability falls generally into two research areas: field/geological and laboratory analysis. Field Progress: An operating field stilling well was installed and 24-hour recorder operations started to measure flows from Linden Hall aquifer. Measurement of spring flows was accomplished at numerous times to calibrate the stilling well readings. The same operation at the Rock Springs spring has been stalled for lack of permission of property owner. Numerous rainfall measuring stations have been established and recording forms completed. The process of gathering pesticide usage on individual farms was commenced to develop the techniques of obtaining potentially sensitive information from each farm usage. Analysis: a list of possible pesticide contaminants has been compiled. Sources include Pesticides in Groundwater: Background Document of 1986, Safe Drinking Water Priority List, and local usage. Extraction method and capillary chromatographic development has been started.

PENNSYLVANIA ENVIRONMENTAL TRACING OF CHEMICALS PATHWAYS IN CROPLAND WATERSHEDS. H. B. Pionke, USDA-ARS, University Park, PA. Report Period: 1/90 - 2/92.

Chemical and ¹⁸O contents of rainfall, streamflow, soil and groundwater during 4 storms in the Mahantango Creek Watershed showed: Subsurface return flow to always dominate the storm hydrograph; storm flow to consistently be about 1/3 rainfall and 2/3 soil plus ground water; and Si, but not SO₄, C₁, NO₃ nor NH₄ to be an equivalent tracer to ¹⁸O. Although the ¹⁸O patterns in throughflow compared to soil matrix waters collected at 20 sites over a 5-storm period was inconclusive, specific storms at selected sites showed much of the quick flow captured at the one-meter depth to be rainfall, not displaced matrix water. Sampling all hydrologic components during storm events over several sites at one time or over several times at one site showed ¹⁸O to be most useful for tracing surface runoff, seep sources, and quick flow through soils, but least useful for separating soil matrix, shallow and deep groundwaters.

RHODE ISLAND ATTENUATION OF GROUNDWATER NITRATE IN RIPARIAN BUFFER ZONES. A. J. Gold, C. G. McKiel, University of Rhode Island, and P. M. Groffman, Institute of Ecosystem Studies. Report Period: 5/91 - 2/92.

While riparian zones dominated by wet soils have been shown to attenuate groundwater nitrate (NO_3^-), more well-drained soils may be much less effective. Information is needed on the specific soil types that have high NO_3^- removal capacity. We are adding solutions enriched with NO_3^- and bromide to groundwater beneath different soil types within a riparian zone during both growing and dormant seasons. Measurements of plant roots and microbial processes are being made to determine what processes are contributing to observed NO_3^- attenuation. Work during this period has focused on experimental site layout and collection of preliminary data. We have found differences in groundwater oxygen levels and microbial activity within the site which should lead to major differences in NO_3^- attenuation.

SOUTH CAROLINA & NORTH CAROLINA TERRAIN CONDUCTIVITY TO QUANTIFY IMPACT OF FARM LAGOONS UPON GROUNDWATER QUALITY. D. E. Brune, Clemson University, P. W. Westerman, North Carolina State University. Report Period: 9/89 - 8/91.

A computer model has been developed which is capable of predicting averaged groundwater ionic strength and anion concentration in soils affected by animal waste lagoon seepage, using surface electromagnetic terrain conductivity as the primary sensing technique. This capability has significantly improved the ability of researchers and soil conservation engineers to assess and predict the impact of animal waste lagoons on groundwater water. Specific accomplishments have included; 1. development of a relationship between soil pore water conductivity and ionic strength and ion composition as affected by lagoon seepage, 2. development of a model of bulk soil conductivity under varying soil texture and pore water conductivity conditions, 3. a sensitivity study which defines the degree of importance of geohydrological conditions and lagoon seepage upon terrain conductivity (based on above models) and compares the predicted response to actual measured terrain conductivity, 4. the effects of the establishment of new lagoons upon groundwater and resulting terrain conductivity.

SOUTH CAROLINA IMPROVED IRRIGATION AND NITROGEN MANAGEMENT OF COTTON IN THE EASTERN COASTAL PLAIN. P. G. Hunt, C. R. Camp, and P. J. Bauer, USDA-ARS, Florence, SC. Report Period: 2/91 - 2/92.

Improved irrigation and fertilizer N management systems for cotton in the Eastern Coastal Plain of the United States will decrease the potential of groundwater contamination by nitrates. A 4-year study of buried microirrigation and N management on plant and soil N status as well as cotton yield was begun in 1991. Water management treatments were buried microirrigation tubing (two spacings) and rainfall only. Preplanting N application was 22 kg/ha; post-emergence nitrogen was added via the irrigation system in one application (90 kg/ha), in five weekly applications of 22 kg/ha, and 22 kg/ha when the GOSSYM/COMAX (GC) model predicted N deficiency (67 kg/ha was applied). No differences in lint yield were found among the N management treatments with irrigation. In the rainfall-only plots, the GC treatment produced 1705 kg/ha lint cotton (3.5 bales); 339 kg/ha more lint than the single N application with 45 kg/ha less N fertilizer. Nitrate movement in the soil and plant will be studied using depleted ^{15}N applied to one row in each plot.

SOUTH CAROLINA WATER QUALITY EVALUATION FOR DUPLIN COUNTY DEMONSTRATION PROJECT. P. G. Hunt, K. C. Stone, USDA-ARS, Florence, SC. Report Period: 9/90 - 2/92.

Agricultural practices on the watershed are typical for the Southeastern coastal plain and include row crop, poultry, swine, and cattle production. Stream water samples have been taken at hourly intervals and analyzed on 8 hour composites since installation (September 1990) at three sites on the watershed. Nitrate, ammonia, and orthophosphorus averaged 1.3, 0.07, and 0.1 mg/L at the background site; 5.7, 1.2, and 0.8 mg/L downstream of the intensive animal production site; and 2.3, 0.2, and 0.5 mg/L at the watershed outlet. This shows distinct contamination and the potential of improved water quality from BMP implementation on the contaminated tributary. Ground water samples taken from fields with row crops have had nitrate concentration around 8 mg/L. High nitrate levels (significantly exceeding 10 mg/L) were observed in ground water monitoring wells

on an undersized swine spray application field. We have worked with extension, SCS, and the landowner to implement improved management of this operation through enlargement of the spray field and through other available options.

SOUTH CAROLINA & KENTUCKY GROUNDWATER QUALITY AS AFFECTED BY PREFERENTIAL FLOW IN STRUCTURED SOILS. V. L. Quisenberry and B. R. Smith, Clemson University and R. E. Phillips, University of Kentucky. Report Period: 10/89 - 2/92.

Experiments were conducted in two important and extensive soils: Cecil sandy loam in SC and Maury silt loam in KY. The research has shown for structured soils that 1) significant amounts of chemicals can move through the soil by macropore flow, 2) less than 20% of the total soil volume maybe involved in the flow process, and 3) macropore flow occurs in the same pores for similar rainfall events. Flow through the subsurface horizons of each is quite similar, but less direct bypass flow occurs in the surface horizon of sandy loam soil. The data show that macropore flow can be directly related to soil physical characteristics, especially structure and texture.

SOUTH CAROLINA, KENTUCKY & ARKANSAS SOIL CLASSIFICATION SYSTEM FOR SOUTHERN REGION BASED ON WATER AND CHEMICAL TRANSPORT. V. L. Quisenberry, Clemson University, R. E. Phillips, Univ of Kentucky, and H. D. Scott, Univ of Arkansas. Report Period: 7/91 - 2/92.

We are developing a soil classification system based on water and chemical transport. We have grouped soils with similar physical (especially structure and texture) and chemical properties. Soils within a group will have some variability, but a given group will transport water and solute quite differently than another group. We are now in the process of validating our tentative classification system. Experiments conducted on soils in Kentucky and South Carolina support the classification system concept and suggest that management practices can be developed to reduce potential groundwater problems.

SOUTH DAKOTA, MINNESOTA & COLORADO TILLAGE INDUCED MICRORELIEF IMPACT ON NO₃ AND ATRAZINE MOVEMENT IN SOILS. D. E. Clay, T. E. Schumacher, S. A. Clay, and J. A. Bischoff, South Dakota State University; G. L. Malzer, University of Minnesota; M. J. Shaffer, USDA-ARS, Fort Collins. Report Period: 4/91 - 2/92.

The research activities have been completed as planned. During 1991, several objectives have been achieved. These include: (i) the initiation of field plots; (ii) installation of lysimeters, TDR, thermocouples, and neutron access tubes in microplots; (iii) obtaining and the analysis of background soil samples for inorganic N and atrazine and alachlor concentrations; and (iv) presentation of research finding at South Dakota Soil Moisture Clinic and Brookings Farm field tours. Preparations are underway for the 1992 growing season, and research activities between the two sites are coordinated.

SOUTH DAKOTA DEVELOP TECHNOLOGIES FOR MANAGING CORN ROOTWORM POPULATIONS WITH REDUCED INSECTICIDE INPUTS. G. R. Sutter, W. D. Woodson, M. M. Ellsbury, L. S. Hesler, Brookings, SD, USDA-ARS. Report Period: 4/90 - 2/92.

A large-scale management program (16 square miles) for corn rootworms was successfully conducted in 1991. Over 3000 acres of maize were treated with a semiochemical-based bait that used 98% less toxin than typically applied for management of these pests. The baits did not appear to adversely affect beneficial insects. Newly developed traps were employed to identify fields harboring pest densities above thresholds and of equal importance, identified fields that did not require treatment. Significant progress was made in development of decision support systems for IPM in maize production which will allow growers to use selected inputs for conducting environmentally sound management practices that are also economically feasible. Improved environmental quality will only be realized when the program has been in effect for consecutive years.

TENNESSEE & LOUISIANA THE EFFECTS OF TILLAGE ON FATE AND TRANSPORT OF PESTICIDES THROUGH UNSATURATED SOIL PROFILES. M. E. Essington, G. V. Wilson, and D. D. Tyler, University of Tennessee, and H. M. Selim, Louisiana State University. Report Period: 7/91 - 2/92.

The objectives of this research are to 1) quantitatively describe the association of fluometuron, metolachlor, and pendimethalin with dissolved organic carbon (DOC) extracted from long-term no-tillage (NT) and conventional tillage (CT) soils, 2) examine the influence of DOC on the sorption, sorption kinetics, and desorption of pesticides by NT and CT soils, 3) quantify the effect of tillage practice on the unsaturated transport of the herbicides, and 4) develop capabilities to mathematical model the unsaturated transport of the herbicides. Laboratory experiments have been initiated to characterize the aqueous association of the herbicides with DOC. Four methodologies are being assessed for their ability to quantify herbicide KDOC values: equilibrium dialysis, water solubility enhancement, gel filtration, and reverse-phase separation.

TENNESSEE & KENTUCKY EFFECTS OF TILLAGE AND CROPPING SYSTEMS ON TRANSPORT OF NITRATE THROUGH HETEROGENEOUS SOILS. G. V. Wilson, D. D. Tyler, J. Logan, University of Tennessee, and G. W. Thomas, R. L. Blevins, Univ of Kentucky. Report Period: 5/90 - 2/92.

In Tennessee, 81% of leachate samples had NO₃-N concentrations below the 10 mg/L MCL. Samples exceeding the MCL occurred during the growing season shortly after fertilization when flow out of the root zone was generally small. When large rainstorms occurred immediately following application as much as 50 kg/ha of NO₃-N was leached. Flow was greatest during the winter and spring when concentrations were below the MCL. In Tennessee, no-tillage appeared to reduce nitrate leaching under cotton and soybean systems. In Kentucky, losses of NO₃-N with no-tillage were considerably higher than with conventional tillage under soybeans and lower under corn.

TEXAS PESTICIDE DEGRADATION BY A GENETICALLY ENGINEERED FUNGUS. C. M. Kennerley, A. Garcia III, Texas A&M University. Report Period: 9/91 - 2/92.

Approximately one hundred transformants of the fungus *Gliocladium virens* containing the bacterial gene (*opd*) encoding for the enzyme, organophosphate hydrolase (OPH) were analyzed for their ability to produce the enzyme over a four week period. Western blotting of concentrated culture filtrate using polyclonal antibodies raised against OPH as probes revealed a weak signal. A fungal plasmid that can serve as a stable foundation for cassette exchanges to facilitate introduction of fungal promoters and other genetic elements has been constructed. A model that describes the amount and extent of fungal growth in a solid matrix is being tested. Hyphal mass is estimated by an image processing technique using algorithms designed to calculate the amount of hyphae in soil as hyphal lengths/cm.

TEXAS HYDRAULIC CONDUCTIVITY AND MACROPORE FLOW IN RELATION TO SOIL STRUCTURE. K. J. McInnes, L. P. Wilding, C. T. Hallmark, Texas A&M University. Report Period: 6/90 - 2/92.

Hydraulic information has been collected from 6 of the 18 soils targeted in this project. Hydraulic conductivity measurements have been made within distinct structural horizons of six soils in the Claypan land resource area of southeast Texas. Over all six soils and horizons, macropore flow, estimated from the difference in flow above and below 0.03 m tension, accounted for 70-80% of the saturated water flux. Large temporal variations in hydraulic conductivities existed in the surface horizons of soils with high shrink/swell characteristics. Hydraulic conductivities for a given soil decreased with depth for most horizons measured. Correlation of results with soil structure/macroporosity morphological properties has been initiated. The information being gathered will allow quantitative measurement of hydrological behavior to be related to data on soil resources that are available through the National Cooperative Soil Survey Program and, thus, provide critical information for evaluation of soil resources relative to nonpoint and point source groundwater pollution.

TEXAS DEVELOP COMPREHENSIVE WATER QUALITY MANAGEMENT MODELS. J. R. Williams and C. W. Richardson, USDA-ARS, Temple, TX. Report Period: 2/91 - 2/92.

A rainfall energy term was added to the SCS curve number based runoff models of EPIC and SWRRB to improve accuracy. A manure land disposal management component was developed for EPIC. In response to the SCS SWRRB Evaluation report, we have assembled a sediment yield data set consisting of 3,695 storms on 63 watersheds. We used these data to evaluate MUSLE and two versions of a four-parameter equation. The small watershed version (areas \leq 71.2 ha) of the

four-parameter model predicted sediment yields slightly better than the other two equations. We also assembled a large peak runoff rate data set from 170 watersheds throughout the U.S. Tests with these data indicate that the SWRRB peak rate simulator is superior to TR-55 in tracking seasonal variability. We plan to include the new sediment yield equations and TR-55 as options to MUSLE and the SWRRB peak rate simulator.

TEXAS, GEORGIA & FLORIDA MANAGEMENT OF DAIRY WASTE TO MINIMIZE POTENTIAL GROUNDWATER CONTAMINATION. M. L. Wolfe, M. A. Sanderson, K. J. McInnes, Texas A&M Univ, and M. Cabrera, Univ of Georgia, A. R. Overman, Univ of Florida. Report Period: 7/91 - 2/92. One hundred forty-four 0.3 m diameter PVC tubes (microplots) were pressed into a 0.5 ha plot of "Coastal" bermudagrass. Non-labeled and ¹⁵N-labeled dairy waste will be applied to the microplots in early spring 1992. Forage and soil samples from plots of 'Coastal' bermudagrass established in 1990 and 1991 are being analyzed for nutrient concentrations. The plots received four rates (lb N/ac) of solid manure or liquid effluent. Winter wheat and tall fescue were interseeded into selected plots. Forage yields indicated no response to manure application, probably due to high levels of residual soil N. Simulation models which relate dry matter production and N concentration of forage grasses to applied N, harvest interval, and water availability, were shown to be applicable to two sets of data from Texas. Two manuscripts were submitted for publication. The LEACHM model is being evaluated for simulating the water and nitrogen balances related to the land application of dairy wastes.

UTAH OPTIMIZING IRRIGATION MANAGEMENT FOR POLLUTION CONTROL AND SUSTAINABLE CROP YIELDS. L. M. Dudley, R. J. Hanks, R. C. Peralta, Utah State Univ. Report Period: 9/89 - 2/92. A simulation model and an optimization model have been created and validated. Simulation model salt profiles were compared with those observed in a fifteen year study of irrigation with saline water. The optimization model is calibrated with the simulation model results. The optimization model computes irrigation schedules and water applications that maximize the amount of available water and limit the flux of salt from the bottom of the root zone to specified values. The simulation model has been used to investigate the effects irrigating with minimum leaching on crop yield and root zone salinization. It has been found that leaching can be postponed for a number of years. This could result in significant water savings and a reduction in pollution.

UTAH ECONOMIC INCENTIVES FOR MANAGING NON-POINT PESTICIDE POLLUTION OF GROUNDWATER: A PROTOTYPE APPLICATION. T. F. Glover, R. C. Peralta, H. H. Fullerton, Utah State University. Report Period: 9/90 - 2/92. A one-dimensional (vertical unsaturated flow) crop production/contaminant management model has been used to demonstrate that contamination of groundwater in the Davis-Weber area can be partially controlled by water table management through increased pumping but wells used for farm production purposes decrease in discharge. A regional groundwater planning model has been used to demonstrate that optimal steady state groundwater extraction rates in the same region can increase to over 150% of current rates but again discharge from wells used for irrigation decrease in prime agricultural areas of the region. Controls such as contamination taxes and water taxes are projected to cause significant changes in cropping patterns and reductions in land being irrigated in the region. Uniform policy imposition does not achieve private economic efficiency or a social optimum.

VERMONT EFFECTS OF CORN MANAGEMENT SYSTEMS ON NITRATE LEACHING POTENTIAL. F. R. Magdoff, W. E. Jokela, R. P. Durieux, H. R. Brown, Univ of Vermont. Rpt Period: 8/89 - 12/91. The N management systems study was continued at the Fay Farm (silt loam soil). There were no yield differences between plots fertilized according to the routine recommendation system (RRS) and the Pre-sidedress Nitrate Test (PSNT). However, end of season (residual) soil NO₃-N to 1.2 m was 54 and 92 kg/ha less in the PSNT with and without manure system respectively than in the RRS. This is the second year that use of the PSNT resulted in lower NO₃-N leaching potential than use of the RRS. Groundwater NO₃-N has gradually declined during the experiment, but also

fluctuates with groundwater level. This experiment will continue through 1994 under CSRS Water Quality Project "NITROGEN MANAGEMENT SYSTEMS FOR CORN TO REDUCE NITRATE LEACHING."

VERMONT & NEW YORK NITROGEN MANAGEMENT SYSTEMS FOR CORN TO REDUCE NITRATE LEACHING. F. R. Magdoff, W. E. Jokela, R. P. Durieux, University of Vermont, H. Van Es, S. D. Klausner, L. D. Geohring, Cornell University. Report Period: 5/91 - 2/92.

Experiments were initiated on a clay and on a sand in Vermont. Soil matrix potential, weather and soil nitrate levels were monitored during the growing season. Treatments were: a) Check; b) fertilizer N applied according to the Pre-sidedress Nitrate Test (PSNT); c) same as (b) but plots also received manure. Residual nitrates for treatments (b) and (c) to 1.2 m were about 60 kg/ha on the clay soil (check $\text{NO}_3\text{-N}$ is 46 kg/ha) and about 28 kg/ha on the sand (check $\text{NO}_3\text{-N}$ is 13 kg/ha). On the sand the PSNT with manure treatment yielded higher than PSNT without manure, but not on the clay. Sites have been selected in New York and instrumentation installed for continuous monitoring of NO_3 leaching in 1992.

VIRGINIA SOIL MINERAL NITROGEN AS A PREDICTOR OF NITROGEN FERTILIZER NEED OF WINTER WHEAT. M. M. Alley, P. C. Scharf, Virginia Polytechnic Institute and State University. Report Period: 7/90 - 2/92.

The first year of field experiments has been completed and the data analyzed; the second year of field experiments is underway. Results from the first year indicate that soil mineral nitrogen (N) measurements probably will not be useful for predicting optimum N rate at the first spring application, but tiller (shoot) density measurements appear very promising for making this prediction. A tissue-test system based on previous research is in place for making field-specific N rate recommendations at the second spring application. Making two spring N applications reduces nitrate leaching potential relative to the traditional single spring application, but for growers unwilling to make two applications, nitrate-N to 90 cm depth in January appears promising as a predictor of optimum N rate for a single application. These three tests combine to form a powerful and flexible integrated N rate recommendation system for winter wheat in the mid-Atlantic region. This system has the potential to be widely used by growers and to reduce nitrate leaching to groundwater by eliminating unnecessary or excessive N fertilizer applications. The second year's results will be used to evaluate and modify the two new components of the system; if favorable, technology transfer will begin.

VIRGINIA COMPOSTING AS A MEANS TO DISPOSE OF PESTICIDE WASTE. D. F. Berry, D. E. Mullins, G. H. Hetzel, R. W. Young, Virginia Polytechnic Institute and State University. Report Period: 7/90 - 2/92.

Composting, or solid state fermentation (SSF), was evaluated as a means to dispose of formulated pesticide waste. In sphagnum peat moss-filled bioreactors (constructed from 38-liter Rubbermaid waste containers) containing atrazine (herbicide) at loading rates of 1.4, 2.0, and 7.23 g kg^{-1} (dry weight basis), solvent extractable atrazine decreased to an undetectable level (day 104 of incubation), 95% (day 260), and 98% (day 245) of starting levels. Extractable carbofuran (insecticide) in peat-filled bioreactors with loading rates of 0.7, 1.8, and 5.0 g kg^{-1} decreased to undetectable levels within 100 days. Degradation of a prolonged lag period was observed for atrazine degradation at the highest loading rate. Disposal of formulated pesticide waste using SSF techniques represents a viable alternative to other available more expensive and technically sophisticated methods.

WASHINGTON DEVELOPMENT OF A SPATIAL DECISION SYSTEM FOR FARM MANAGEMENT OF NITROGEN FERTILIZER APPLICATIONS. D. J. Mulla and G. S. Campbell, Washington State University. Report Period: 8/89 - 7/91.

Applying variable rates of fertilizer is an alternative to the conventional practice of applying uniform rates. Research was conducted on a 57 ha irrigated farm in central Washington state to develop techniques for producing management maps for variable rates of nitrogen fertilizer. Soil properties, crop growth patterns, irrigation applications, and movement of a bromide tracer were monitored during the study. Variability in leaching was found to be closely related to spatial

patterns in soil texture and irrigation depth. Techniques involving geostatistics, geographic information systems, and joint frequency distributions were used to develop management maps of leaching potential. These maps could be used to determine how to fertilize each management zone within the field with an appropriate rate or blend of nitrogen fertilizer.

WASHINGTON & OREGON ON-FARM MANAGEMENT OF GROUNDWATER NITRATE POLLUTION IN PACIFIC NORTHWEST IRRIGATED AGRICULTURE. N. K. Whittlesey, D. Mulla, M. Frasier, Washington State Univ, R. Adams, G. Perry, M. English, Oregon State Univ. (Three awards). Report Period: 7/89 - 2/92.

Biophysical crop models have been validated for local conditions and modified to control irrigation uniformity. Optimization models linked to the crop models are used to evaluate managerial and policy options for abatement of nitrate pollution in groundwater from irrigated agriculture. Results indicate that up to 40% of current nitrate emissions to groundwater could be eliminated through improved irrigation and fertilization management with minimal loss of net farm income. Additional increments of abatement become increasingly more expensive. Policies affecting farmer use of water and fertilizer are most effective in achieving desired levels of emission control.

WEST VIRGINIA NEMATICIDE MOBILITY AND BIODEGRADATION: EFFECTS OF ORCHARD SOIL MANAGEMENT. J. Kotcon, A. Sexstone, West Virginia University, D. Glenn, USDA, Kearneysville, WV. Report Period: 5/90 - 3/92.

This project evaluates the influence of three orchard floor management systems, clean cultivated, herbicide treated, and killed sod, on the mobility and biodegradation of the nematicides carbofuran and fenamiphos. Degradation of fenamiphos was faster in herbicide treated than in killed sod and was faster than for carbofuran. Three enrichment cycles increased degradation of carbofuran ≥ 5 -fold. A methylcarbamate hydrolase (*mcd*) gene probe is being used to determine diversity of carbofuran-degrading microbial populations. Total bacterial DNA extracts from untreated soil hybridized with the *mcd* gene probe as did DNA from carbaryl-degrading bacteria; however other carbofuran-degraders did not.

WEST VIRGINIA WATER QUALITY IMPACTS OF AGRICULTURE IN SOUTHEAST WEST VIRGINIA. G. C. Pasquarell, D. G. Boyer, D. P. Bligh, USDA-ARS, Beckley, WV. Report Period: 7/90 - 2/92.

Preliminary results demonstrate the acute sensitivity of Karst conduit ground water to animal grazing practices. A direct relationship has been demonstrated between conduit water nitrates and percent agricultural land use. Strong seasonal trends in atrazine concentrations correlate with the period of basin-wide application. Fecal bacterial levels, however, do not appear to correlate primarily with agricultural activity. The following tasks remain: 1. Determine contaminant variations during high runoff, 2. Complete sampling within cave streams, 3. Establish field sites for study of sinkhole contaminant transport. Results should lead to new management practices for Karst terrain.

WEST VIRGINIA BACTERIAL QUALITY OF POINT-OF-USE FILTERS USED FOR TREATMENT OF RURAL GROUNDWATER SUPPLIES. J. W. Snyder, C. N. Mains, R. E. Anderson, and G. K. Bissonnette, West Virginia University. Report Period: 8/89 - 8/91.

Water quality was monitored for 24 rural, domestic groundwater supplies treated with point-of-use (POU), powdered activated carbon (PAC) filters. Heterotrophic plate count (HPC) densities were generally elevated by 0.86 and 0.20 logs of magnitude, respectively, for spring and drilled well water systems in PAC-treated effluents following an overnight stagnation period as compared with HPC in untreated influents. HPC densities in PAC-treated effluents could be significantly reduced below influent levels, however, after flushing the POU device for two minutes. PAC treatment significantly reduced the number of coliforms in product waters. Aside from periods of nonusage, such as overnight, PAC treatment did not appear to compromise the microbiological quality of private drinking water supplies.

WISCONSIN SAFE ON-FARM DISPOSAL OF DILUTE PESTICIDE WASTES. G. Chesters, J. M. Harkin, M. A. Anderson, H. W. Read, M. A. Aguado, C.-P. Chen, University of Wisconsin-Madison. Report Period: 7/90 - 2/92.

Surveys identified the most widely used pesticides in Wisconsin. Some rinsates are used as make-up water but disposal of mixtures containing incompatible pesticides is still problematic. Sintered TiO₂ was used to destroy pesticide residues by photocatalysis in two bench-scale reactors with glass flow-through cells coated with TiO₂ films and one with a packed bed of porous TiO₂ pellets. Increasing light intensity raises degradation rates of formic acid used as a standard but lowers energy efficiency. Atrazine disappeared from irradiated solutions at 1.4 ppm/hr. Chemical treatments of mixed pesticide wastes were compared with photocatalysis: Pesticide detoxification by dechlorination through hydrolysis, assessed by Cl⁻ production, showed that fly ash works but not ag lime. Degradation studies using ultraviolet-irradiated H₂O₂ are proving more effective. Economic feasibility of the various techniques is being studied.

WISCONSIN & NEW YORK USING GROUND PENETRATING RADAR TO IMPROVE MONITORING AND PREDICTING PREFERENTIAL SOLUTE MOVEMENT IN SANDY SOILS. K.-J. S. Kung, University of Wisconsin-Madison; T. S. Steenhuis, J.-Y. Parlange, Cornell Univ. Report Period: 6/90 - 2/92. Preferential flow initiated by the funneling mechanism in sandy unsaturated soil is unambiguously demonstrated. The capability of GPR technology to nondestructively "see through" a soil profile and obtain accurate information on the layering structure in sandy soil is also demonstrated. A finite element solute transport model suitable for predicting transport in layered sandy soil was developed and validated. A technique to reconstruct the 3-D soil layer structure from 2-D GPR images was developed. Results have reached scientists and the general public through presentations and publications. We are currently focusing on how to filter out noises and false images from raw GPR data by 3-D migration and deconvolution.

WISCONSIN MOVEMENT OF ATRAZINE AND ALACHLOR THROUGH THE UNSATURATED ZONE: MODEL CALIBRATION AND VALIDATION. K. Mc Sweeney and B. Lowery, University of Wisconsin-Madison. Report Period: 6/89 - 2/92.

The study was designed to explain differences in apparent rate and amount of movement of herbicides (atrazine and alachlor) through two broadly similar soils in irrigated portions of the Lower Wisconsin River Valley (LWRV) and Central Sands Area (CS), and encompasses field and laboratory experiments and simulation modeling. Field work, which includes evaluation of management practices to reduce herbicide transport, has been concentrated in the LWRV because groundwater is much faster in the LWRV soil than in the CS soil. Rapid water movement coupled with a lower intrinsic potential of the soil constituents to bind and degrade contaminants help to explain the larger ground-water contamination susceptibility associated with LWRV soils. Findings are being used to refine simulation models for extrapolation and information dissemination.

WISCONSIN PREFERENTIAL MOVEMENT OF WATER AND AGCHEMICALS IN SANDY SOIL WITH ANIMAL BURROWS. J. M. Norman, K. McSweeney, B. Lowery, University of Wisconsin. Report Period: 7/91 - 1/92.

Weekly measurements of the number of ant burrows and leaf area index were made during the 1991 growing season on 66 plots in a corn field (under different irrigation, tillage and nitrogen treatments) located near Arena, WI. Soil pH, organic matter, phosphorous and potassium content, total dry matter and yield were measured for the 66 plots at the end of the season. Tension infiltrometers were used to measure infiltration rate in areas with and without ant burrows. Preliminary results indicate that (1) ant burrow abundance tends to be reduced by irrigation, conventional tillage and reduced nitrogen application, and to be increased by high phosphorous and potassium content and pH about 6.0 (2) infiltration rate increased by 33.5% at zero tension when an ant burrow is present and the water flows into individual burrow openings at rates ranging from 1.5 to 7.3 cm³/sec depending on the size of the burrow (3) six excavated ant burrows varied in depth from 20 cm to 75 cm. Laboratory experiments are initiated on soil columns to study water and chemical movement in the presence of ant burrows.

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